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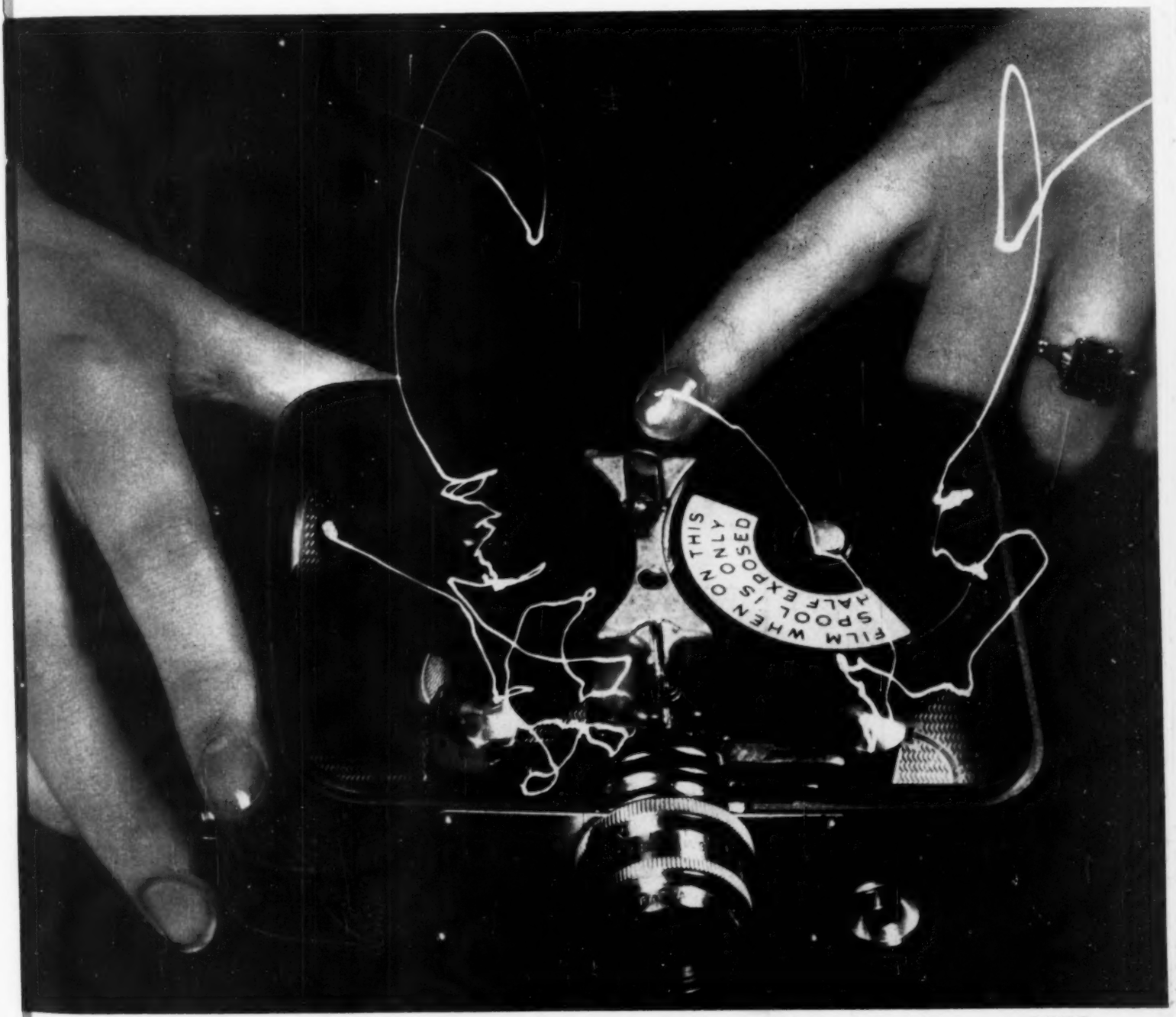


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## THE COVER

A CYCLEGRAPH of the loading of a CITATION movie camera manufactured by the DeJur-Amsco Corporation. This technique, which was developed by Frank B. Gilbreth, demonstrates the motion path required in loading the CITATION camera. The camera was designed to simplify the loading motions.—*Photo Courtesy of DeJur-Amsco Corporation, Long Island City, N. Y.*

## CONTENTS


Management's Responsibility for Cost Reduction
By Phil Carroll ..... 3

Basic Motion Timestudy
By Herbert Lynch ..... 4

Time Study and Labor Relations
By Harold O. Davidson ..... 7

The Industrial Engineering Audit
By Harold R. Nissley ..... 9

A Missing Ingredient
By Wilbur R. Meredith ..... 11

Systems—The New Field for Industrial Engineering
By Alan J. Levy ..... 13

Random Ratio-Delay
By G. Eric McAllister ..... 15

In Perspective—"How Save Time" ..... 17

A Reply to Davidson's Review of Work Measurement
By Adam Abruzzi ..... 18

Organizational Field Studies at Columbia University
By David B. Hertz and Albert H. Rubenstein ..... 19



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## PRESIDENT'S MESSAGE

**Frank F. Groseclose**

Strange as it may seem, as I ride the Southern Pacific "Starlight" northward to Stanford to resume some Summer teaching as a visiting professor at one of this country's greatest Graduate Schools of Business, I have found a place of relative quiet.

At home with a small radio in every room except the one with television and at the office where I keep open doors to a number of research engineers it is almost impossible to find time for even a short period of concentrated thought.

In spite of present day handicaps there is much work to be done and considerable talk about it but too few people who are willing to roll up their sleeves and get at it. A year ago I got an urgent call from the Navy to come to the West coast. Today a call came from the Pentagon to come East on invitational orders to discuss Army problems. Believe it or not I turned this last one down. Not because of a burst of will power but simply because I could not physically be on both coasts during the same hours of one particular day or few days.

Notice that I did not say that I could not be on both coasts the same day, this is relatively easy. As a matter of fact I can leave my West coast office after a full day there, eat supper (dinner if you prefer) and have time to smoke two fat cigars (if I want to or two) before catching a plane that would put me in the Nation's Capital in time for morning business. A late lunch there gives me time to take the plane that gets me home for my usual bed time.

So what? I am reminded of the story of the Army Colonel who used his military priority rights to "bump" a civilian from a plane leaving Washington. When he got to his destination he was informed

(Continued on Page 23)

# Management's Responsibility For Cost Reduction

**By Phil Carroll**

Professional Engineer. Author, "Timestudy for Cost Control," "Timestudy Fundamentals For Foremen," "How To Chart Timestudy Data," "How To Control Production Costs," McGraw-Hill Book Company, Inc., New York.

Management is responsible for returning a fair profit to those people who furnish the money. And that profit has to be enough to pay our exhorbitant taxes. As I put it, "Industry pays all the bills." Industry provides our only way to create wealth.

Failing to make profits, a business folds up. Many do every year. The reason usually given may be shortened to the one word, "mismanagement." This term takes in lots of territory. Regardless, the management that failed ran out of money. It spent more than it took in for too long a time.

### TWO PROFITS

The profits it failed to make were lost in either or both of two places. One is the profit that should have been in the selling price. The other is the profit that should have been made in cost reduction —cost improvement—cost control.

We should recognize these two places where profits are made or lost. With excellent internal performance, a company can lose out if it wraps up a ten dollar bill with each shipment because the price is wrong. On the other hand, the management must push new costs below previous costs if it is to stay ahead of competition.

These two approaches may seem to be one and the same. They are in part. Their differences are what I want to stress.

### KNOW YOUR COST

First, can we agree that raising prices is not the way to make profit? Isn't that the basic fault in the cartel system in Europe? Isn't that what is happening in coal mining and building construction? People are pricing themselves right out of business.

Let's look at this the other way. Two factors are present. One is to keep away from trying to compete in fields where you are unskilled. Trying to compete in the wrong fields is another subject. So we will take up the other factor. It is to know your costs. That is our starting point.

Now, most of us think we know what our costs are. We do in some respects. In industry, we figure labor and material to the fourth decimal place. But we spread on our overheads with a shovel. Here is where our mistakes are made. Hence our total costs are misleading. As a result, some of our management decisions are wrong and costly.

This factor is important in any business that has mixed products. Let me emphasize with two examples. In one company, the overhead was analyzed by products. Then it was shown that on one product the engineering cost alone was more than the selling price. In another, the cost to process an order through the office "paper mill" was studied. After that, we found that it took $85 worth of sales just to break even on an order. In simple arithmetic, how can you make money if it costs you $5 to charge a customer 25 cents for an item he orders?

### WHAT IS COST?

Obviously, you can't. You have to get back the loss of $4.75 on some other part of your business, and more, or you fail to make a profit overall.

Obviously too, you can't expect to make a profit on everything. If you did, you would never venture into a new design or a new market. My point relates to cost control and cost reduction. I believe that you should know what your costs are in order to know where to apply management skills.

To direct management skill seems necessary to me. In the first place, some parts of cost are very much greater than others. Ordinarily, these larger elements are more susceptible to cost reduction efforts. Then too, our average manager has only 16 hours in his business day to work on cost reduction. Thus it seems to me necessary that we provide better direction finders for managing costs.

### MANAGEMENT ERRORS

You can say that all costs are too high. I agree. To argue otherwise is to admit that progress has stopped. But a general reduction will not correct the losses on specific products. These are many and varied. I call them "management errors."

They result from failures to plan, failures to specify and, perhaps most costly, failures to follow-up. All represent possible reductions in cost. The possibilities change with quantity and expense. Some wastes are less expensive at a given moment than the cost to reduce them.

Yet my experience is that we rarely know the costs of management errors. They are buried in totals. One common example is the ordinary piece work rate used for wage incentive. It contains details of wasted effort that show up only when you make an analysis of its details.

In overhead, we have the same things, only more so. One example is the costly report that no one looks at. We have more waste in overhead simply because we haven't studied it. Reducing these leaks is management's basic responsibility.

### MEASURES AND INCENTIVES

Keeping the business alive comes first. Upon its success depends the livelihoods of its management, its employees and its community. And the business has competitors with the same responsibilities for survival. Here we can see that competition, as we know it, really is competition between managements rather than between firms.

The managements you are pitted against are all those striving to get the customers' dollars. This narrows the question to the better product at the same or a lower price. That spells cost reduction every way I look at it.

For managements to compete and survive, I think they need measures and incentive. They need measures to point out the losses. They need incentives to get action to reduce those losses. Neither measures nor incentives have been mentioned in the so-called "executive development" plans I have read about. Without measuring results, how do we know that the executive has developed? And if he is developed, how do we get him to take action to reduce costs without incentives of some kind?

### DESPERATION SLASHES

Probably, I'm the one who is out of step. Even so, I think we have some untapped gold mines in our own back yards. I said that another way to one manager. My comment was, "George, I'm beginning to wonder if you folks really do want to save money." The incentives weren't strong enough to overcome the "can't be dones."

Why do we wait until we're in a jam before we take action to reduce costs? Under pressure, the average management orders a reduction of 15 per cent. I call this "desperation slashing." It cuts the cost, yes. But it penalizes the efficient department. And maybe, all that happens is that the work is postponed until "good times" return again. I worked in a plant where budgets on maintenance work operated exactly that way.

It seems to me that cost reduction should be more deliberate. One experience may illustrate. In this plant, the Chief Timestudy Man received instructions to get $132 out of the cost of one product. He did. Perhaps he could have taken even more out of the cost. I don't know. At any rate, the cost reduction goal was set and it was met. This method is used by some automobile people, I am told.

The fault I find with the method illustrated is that it is only an improvement on the desperation approach. It is one major cost reduction on one product at one time. Nevertheless, it is a step in the right direction. I believe that we need one more step in that same direction. My suggestion is that we should have planned reductions on all products all the time. Each year, we should wring out some planned amount of expense.

In contrast, observe the usual methods improvement program. We put on a big

(Continued on Page 10)

# BASIC MOTION TIMESTUDY

## NEWEST SYSTEM OF PREDETERMINED MOTION-TIME VALUES

By Dr. Herbert Lynch, P.E.
117 E. Third St., Charlotte, N. C.

By now, most Industrial Engineers who are concerned with establishing time standards are trained in or acquainted with one or more of the several systems of setting time standards from tables of predetermined time values for manual motions. These include Methods Time Measurement, Work Factor, Motion-Time Analysis and Basic Motion Timestudy. A few lesser known systems have been developed by large manufacturing concerns for internal use and, because of personnel turnover, these systems are being used to a limited extent outside the companies that developed them.

In order to understand why Timestudy Specialists are becoming so interested in these relatively new techniques, it may be well to list the advantages (and limitations) of predetermined motion-time values:

### ADVANTAGES:

1. Biggest advantage, perhaps one that alone can justify their use, is that the techniques force the user to become method or motion-conscious. The usual result is that the operation is work simplified to a greater extent than if conventional timestudy had been employed to establish the standard. This results in labor cost savings and helps avoid "creeping" methods changes introduced by operators which, over a period of time, tend to make the time standard "loose."

2. Time standards can be determined before production starts, in some cases even when operations are being planned. This means that more reliable estimated costs (and more realistic pricing) can be had for new or redesigned products or processes. Furthermore, the time standard can be released when the job starts with the result that there is none of the usual "holding back" on the part of the operators until the standard is established.

3. Costs of alternate methods of production can be evaluated quickly and fairly accurately.

4. The shorthand method of recording motions results in a more accurate description of the job method than the conventional description of elements. However, the method of motion description could also be employed in stopwatch timestudy with the same benefits provided the user understands the value and significance of the details recorded. These descriptions are also useful in training operators to follow the standard method.

5. Time standards are more likely to be consistent or in line with other standards. This is especially true where the standard data method of conventional stopwatch timestudy is not being used.

6. The stopwatch, hated symbol of "efficiency," is relegated to the minor role of obtaining machine and process times or check studies.

7. Time standards can be recomputed quickly and at low cost when methods changes are effected.

8. Performance Rating is not needed after the predetermined time value system is established. However, it must be used, of course, if stopwatch timestudy is employed to check a disputed standard.

### LIMITATIONS:

1. Requires judgment of a high order to decide exactly what motions could and should be employed by the "average" qualified operator to perform the work cycle; whether certain motions can be performed simultaneously with right and left hand, whether grasps and positionings can take place without the eyes being focused on point of contact, and other difficult considerations.

2. None of the systems are capable of establishing accurate time standards for all manual work. Typewriting is an example of a job that does not lend itself to analysis. As yet the systems are not truly universal.

3. If the job consists of highly repetitive motions or has a very short cycle, the analysis must be exact and, even if it is exact, inaccuracies inherent in the time values may result in a wrong answer. Because of the tendency of high and low values to "average out" this is not usually a problem on average length or long cycle jobs.

4. On non-repetitive work, standards usually are too "tight" because no provision is made in the time values for hesitations, false motions, etc. that probably should be expected. Of course an arbitrary allowance can be made but such allowances are seldom more than guesses. The stop watch may be more economical for this type of study.

5. The problem of fatigue allowances on heavy labor jobs or jobs subjecting body members to undue local fatgue is ignored and remains unsolved. Stopwatch timestudies of long duration (several hours or full day), provided the operator is qualified to do the work and is cooperative, can be used to establish standards that are equitable, even if the fatigue "allowance" remains indeterminable.

6. If a predetermined time standard is disputed or does not seem to work out, stopwatch timestudy must often be used to find out why.

7. Training of analysis is longer and requires highly skilled instructors. The techniques cannot be self-taught properly. This last statement may be true of stopwatch timestudy also, but to a lesser extent.

8. None of the systems can determine time values for machine controlled or process controlled portions of a work cycle.

### HOW BMT TIME VALUES WERE ESTABLISHED:

Basic Motion Timestudy (BMT) was developed by the firm of J. D. Woods & Gordon, Ltd., Management Consultants, Toronto, Canada, after the other three previously named systems were developed. Indeed the Woods & Gordon engineers who developed BMT had been trained in two of the other three systems. However, they were not completely satisfied with the method of classifying motions nor with certain portions of the time data provided in the other systems. Using the time honored approach of the scientist and engineer, they conducted a series of carefully controlled experiments that encompassed a great variety of motion patterns. One variable at a time was introduced into each basic motion pattern so that the effect of that variable and that variable alone could be measured with relative accuracy. Of course, no pretense was made that all possible variables were segregated and measured, but it is believed that the major variables — those that have an appreciable effect on time required to make a motion — have been identified and measured. Of course the originators of the other systems have also identified most if not all of the major variables but, because their data are not based on controlled experiments, and seldom was it possible to isolate any single variable completely, it seems likely that their measurement of the effect of these variables was subject to greater error.

Proponents of all four systems point to the fact that their system works — that it does provide workable time standards. There is little question but that a skilled analyst can obtain satisfactory results with any of the four if he has had considerable application experience. Chances are he could even make a rather poorly designed system work satisfactorily. Consciously or sub-consciously, he would learn the weak points and how to compensate.

### SOME OF THE MAJOR DESIGN FEATURES OF BMT:

1. "Reach" and "Move" tables are combined. No appreciable difference in time values for reaching with the empty hand or moving the hand with an object weighing less than two pounds was found, nor was any appreciable difference found in the time to make finger movements of

a given length as compared with hand or arm movements of the same length.

*Classes of Reaches or Moves*:

A—Motion is terminated abruptly by a stopping object (commonplace example: hit top of desk with fist)

B—Motion is terminated in space by muscular control (example: toss match aside to ground)

C—Motion is terminated by grasp or placement (or the equivalent) (Example: reach to and grasp machine lever)

In addition, there are the BV and CV classes which are B & C Reaches and Moves requiring visual control to terminate the motion.

All five classes of reaches-moves are related to the length (in inches) of the path of the motion.

2. There are no separate time values for either grasp or release. However, a separate table for precision with which the finger tips must be located to effect a "grasp" or "placement" (release) provides values which are additive to the basic Reach or Move table. Several values for precision of location of finger tips (i. e. ½", ¼", ⅛", etc.) are provided. Moreover, since it was found that the precision of the grasp or placement affected the time of reach or move *throughout its length*, precision allowances increase as the distance reached or moved increases.

3. A second additive is required when reaches or moves are performed simultaneously by right and left hands. Time values are related both to the separation distance of the terminal points of the reaches or moves and the precision (accuracy of location of finger tips) required.

4. Turns (motions about long axis of arm) are measured in degrees turned rather than inches moved, but the same five classes of motions established for reaches and moves are utilized. The additive allowances described above are used for turns also.

5. Weight or force is handled by a separate consideration of the necessity of gaining control (by applying pressure), acceleration, and deceleration of the object. The weight of the object in pounds and the distance of the move are factors affecting the time value (which is the third possible additive to the basic Reach-Move or Turn tables values). The separate treatment of apply pressure, accelerate and decelerate provides a high degree of flexibility and should tend to promote accuracy in the handling of the weight or force variable.

6. Treatment of times for motions of body members other than arms-finger are handled in a very similar manner to one of the other systems. (Indeed, it is based on it.) However, the time values are somewhat different.

**MAJOR ADVANTAGES OF THE BMT METHOD: (These are the personal opinions of the author)**

1. It is believed that the BMT system is simpler and is easier to teach and understand. The simplification has not been at the expense of accuracy, however. Classification of motions is fairly clean-cut and logical, and two analysts working independently are likely to classify the motions in the same way.

2. Because of the way the time values were developed, the effect of each major variable has been carefully segregated and probably measured more accurately. Moreover, the time values are relatively accurate *throughout* the ranges given.

3. The experiments used to determine the values are reproducable by anyone wishing to verify the values.

*A Word of Caution*: The time values in any system of predetermined motion times must be interpreted in the terms of the system of establishing time standards used by the originators. They are *not* necessarily compatible with your system of establishing time standards by stopwatch timestudy. The production rate indicated by the BMT values can be bettered by the average qualified *incentive* operator by about 30% provided allowances (for personal and "fatigue") of about 10% are used. As stated earlier, if the operation is particularly fatiguing, an additional arbitrary allowance must be used or "adequate" rest periods provided.

**A BMT APPLPICATION EXAMPLE**

OPERATION "B" TRANSPORT MARBLES

(from the Society for Advancement of Management Rating of Time Studies Films)

Although this is one of the three "laboratory type" operations in the S.A.M. series of twenty-four rating films, it is

## BASIC MOTION TIMESTUDY VALUES*

**(Expressed in Ten Thousandths of a Minute)**

### REACH OR MOVE

| Inches | ½ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 27 | 30 | 36 | 39 | 42 | 45 | 47 | 50 | 52 | 54 | 56 | 60 | 64 | 68 | 72 | 76 | 80 | 84 | 88 | 92 | 96 |
| B | 32 | 36 | 42 | 46 | 49 | 52 | 55 | 58 | 60 | 62 | 64 | 68 | 72 | 76 | 80 | 84 | 88 | 92 | 96 | 100 | 104 |
| BV | 36 | 42 | 48 | 53 | 57 | 60 | 63 | 66 | 68 | 70 | 73 | 77 | 81 | 85 | 89 | 93 | 97 | 101 | 105 | 109 | 113 |
| C | 41 | 48 | 55 | 60 | 64 | 68 | 71 | 74 | 77 | 79 | 81 | 86 | 90 | 94 | 98 | 102 | 107 | 111 | 115 | 119 | 123 |
| CV | 45 | 54 | 62 | 67 | 72 | 76 | 79 | 82 | 85 | 87 | 90 | 95 | 99 | 104 | 108 | 112 | 116 | 120 | 124 | 128 | 132 |

### PRECISION

| Inches | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/2" | 3 | 4 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| 1/4" | 13 | 16 | 18 | 21 | 23 | 25 | 27 | 29 | 31 | 32 | 36 | 39 | 42 | 45 | 48 | 51 | 53 | 55 | 57 | 59 |
| 1/8" | 33 | 37 | 41 | 45 | 48 | 52 | 55 | 58 | 60 | 62 | 67 | 72 | 76 | 80 | 83 | 87 | 91 | 94 | 98 | 101 |
| 1/16" | 60 | 65 | 69 | 73 | 76 | 80 | 83 | 87 | 90 | 93 | 98 | 103 | 107 | 112 | 115 | 119 | 123 | 127 | 131 | 135 |
| 1/32" | 90 | 97 | 102 | 106 | 110 | 114 | 117 | 120 | 123 | 126 | 131 | 135 | 139 | 143 | 147 | 150 | 153 | 157 | 161 | 165 |

### SIMULTANEOUS MOTIONS

| Separation Distance | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/4" Tolerance and over | 0 | 10 | 18 | 27 | 34 | 41 | 47 | 54 | 59 | 65 | 69 | 74 | 78 |
| 1/8" Tolerance and over | 0 | 12 | 21 | 30 | 37 | 44 | 51 | 57 | 63 | 68 | 73 | 78 | 82 |
| 1/16" Tolerance and over | 0 | 15 | 27 | 37 | 45 | 53 | 61 | 68 | 75 | 80 | 86 | 91 | 96 |
| 1/32" Tolerance and over | 0 | 19 | 34 | 47 | 58 | 68 | 77 | 84 | 90 | 97 | 103 | 107 | 111 |

### FORCE

| Apply Pressure Inches | 6 | Start or Stop 12 | 24 |
|---|---|---|---|
| 2 Lbs. | 2 | 3 | 3 |
| 4 Lbs. | 6 | 6 | 7 |
| 6 Lbs. | 8 | 9 | 10 |
| 8 Lbs. | 10 | 11 | 13 |
| 10 Lbs. | 13 | 14 | 16 |
| 15 Lbs. | 18 | 20 | 22 |
| 20 Lbs. | 23 | 26 | 28 |
| 30 Lbs. | 31 | 35 | 38 |
| 40 Lbs. | 38 | 43 | 47 |
| 50 Lbs. | 45 | 50 | 55 |

### TURN

| Degrees | 30 | 45 | 60 | 75 | 90 | 120 | 150 | 180 |
|---|---|---|---|---|---|---|---|---|
| A | 26 | 29 | 32 | 34 | 37 | 43 | 49 | 54 |
| B | 33 | 36 | 40 | 43 | 47 | 54 | 60 | 67 |
| BV | 40 | 44 | 48 | 52 | 56 | 65 | 72 | 80 |
| C | 56 | 60 | 64 | 68 | 72 | 81 | 88 | 96 |
| CV | 73 | 77 | 81 | 85 | 89 | 98 | 105 | 113 |

### BODY MOTIONS

| | | | | | |
|---|---|---|---|---|---|
| Leg Motion (1"-6") | LM | 50 | Turn Body | TB1 | 110 |
| Add Per Inch | | 2 | Turn Body | TB2 | 220 |
| Foot Motion | FM | 55 | Bend | B | 180 |
| Walk One Place | W | 100 | Stoop | S | 180 |
| Side Step (1"-6") | SS1 | 60 | Kneel on One Knee | K1 | 180 |
| Add Per Inch | | 2 | Arise | AB Etc. | 200 |
| Side Step (1"-6") | SS2 | 120 | Kneel on Knees | K2 | 440 |
| Add Per Inch | | 4 | Arise from Knees | AK2 | 480 |
| | | | Sit | Sit | 220 |
| | | | Stand | Stand | 270 |

Time values are for "normal" performance. Average qualified incentive operator will better indicated production rate by 30%. Use with 10% personal and fatigue allowances.

**Caution:** Training and application experience is essential before these time values can be used in a competent manner.

Developed by J. D. Woods & Gordon Limited, Toronto, Ontario, Canada.
Presented by Herbert Lynch & Associates, Charlotte, North Carolina

chosen as an example because the set-up can be physically duplicated and the operation performed by the reader to satisfy himself that the time standard is reasonable.

*Transport Marbles* is a simulated industrial operation in which ordinary spherical glass agates 5/8" in diameter are picked up and transported a straight line distance of twelve inches and released in circular disposal holes which are 3/4" in diameter and 3" apart on centers (holes are not chamfered). Marbles drop through holes into a small box placed under the thin platform in which the disposal holes are drilled. Top of platform, which is 3" x 6" x 1/4" in size, is two inches higher than "table top."

Operation is "dual," the right and left hands performing the identical basic motions simultaneously. The operator is seated comfortably. Centers of the disposal holes are each about two inches from the perpendicular plane passing through the edge of table nearest operator, and a line joining hole centers would be parallel to same table edge.

Marbles are always picked up between thumb and forefinger from exactly the same locations because twin ramps are used to provide a gravity feed. Marbles being picked up are three inches apart on centers, and a line joining centers of marbles is parallel to edge of table nearest operator.

Grasp is only slightly encumbered by small nails (5/16" in height above trough of ramp) which stop marbles in correct position and by the two marbles next in line. Troughs of the ramps are very shallow to provide minimum interference with grasp. Marbles (picked up) should not be elevated more than 1/2" above table top (use ramps of small depth).

**DISCUSSION OF ANALYSIS:**

*Item* 1: Reach to Marble. Since this reach is terminated by a grasp and requires visual control it is class CV. The length of the move is measured at the large knuckle (3rd joint from finger tip) of middle finger and is 12 inches. This motion is performed along an almost exactly straight line. If the path of the motion were an arc, the measurement would be taken along the arc and of course would exceed 12 inches.

*Item* 2: Precision Allowance (P). Experimentation with a spherical object of 5/8" diameter will show that the finger tips must be located within a tolerance of 1/2" in order to effect a grasp. The BMT technique provides a set of rules for measuring tolerance of location of finger tips in all three dimensions but space does not permit listing them. Moreover, the technique permits a different type of analysis when the pick up is best made by not singling out (selecting) a specific part from among many during the reach. In the latter case the analysis might provide extra finger motions at a specified frequency for regrasp or separation movements in lieu of a precision allowance.

*Item* 3: Simo Allowance. Because the two marbles being picked up simultaneously (one each in the right and left hands) are separated by three inches the eyes cannot focus on both pickups at once and thus the simultaneous reach-grasp is slowed down by the necessity of shifting point of focus of eyes. Since separation distance is three inches the table is interpolated between the values of two and four inches. Tolerance is over 1/4" (1/2"), so the top line of values on the simultaneous motions table is used.

*Item* 4: Move to Disposal Holes. Distance is same as reach (12 inches). The move ends in a "placement" in or just above the disposal holes and requires visual control so the class is CV. However, no precision allowance is needed because the disposal holes are 3/4" in diameter and the marbles can be placed within a tolerance of only 3/4" and will still roll into the holes.

*Item* 5: A Simo Allowance as described in item 3 is needed.

**DISCUSSION OF RESULT:**

The total time value for one cycle (two marbles) is .0232 minutes. This is so called "normal" time. An allowance of 10% for personal needs and "fatigue" would be added since the BMT time values were developed under a time standards system which provides a 10% allowance for "light" operations. After the 10% allowance is added the time "standard" would be .02552 minutes per cycle or 25.52 minutes per 1000 cycles (2000 marbles). Of course, no provision has been made for auxiliary elements of work such as filling ramps, etc.

The average qualified incentive operator would better the standard rate of productivity indicated by 30%. Thus he should *average* 25.52 divided by 1.30, or 19.63 minutes per 2000 marbles throughout the working day. This 30% spread between "normal" and incentive performance is a design feature of the Woods & Gordon Time Standards System.

The BMT "normal" time of .0232 compares very favorably with a mean normal time of .0239 (expressed in the Woods & Gordon System) set on a film of this operation by the 1,200 time study engineers who participated in the nationwide Rating Survey conducted by S.A.M. It is only fair to point out that such close agreement (3% variation) is probably partially due to chance.

Moreover, after a considerable amount of practice, the cycle can be performed with the eyes focused continually on the pick-up area. This method calls for a different analysis which carries a lower time value. In the S.A.M. films the operator's eyes were continually focused on the pick-up area but this is not evident to anyone viewing the films.

By now, it should be apparent to the reader that it is essential to specify the exact method and motion pattern that is to be used and that it takes considerable skill and judgment to specify the "right" motion pattern.

**BMT ANALYSIS**

For right hand (left hand analysis would be identical)

| *Item No.* | *Description* | *"Shorthand" Symbol* | *Distance* | *Table* | *Time in ten-thousandths of a minute* |
|---|---|---|---|---|---|
| 1. | Reach to marble | R12CV | 12 inches | Reach or Move | 95 |
| 2. | Precision allowance | P1/2" | 12 inches | Precision | 14 |
| 3. | "Simo" allowance | Simo | 3 inches (separation) | Simultaneous Motions | 14 (interpolated) |
| 4. | Move to Disposal holes | M12CV | 12 inches | Reach or Move | 95 |
| 5. | "Simo" allowance | Simo | 3 inches (separation) | Simultaneous Motions | 14 (interpolated) |
| | | | | | Total 232 |
| | | | | | or .0232 minutes per cycle |

## Book Review

*"Principles of Management"*
By George R. Terry,
Richard D. Irwin, Inc.,
Homewood, Illinois, 1953, 647 pages, $8.00
— by Robert M. Eastman, Associate Professor of Industrial Engineering, Georgia Institute of Technology

While Prof. Terry has written this book primarily as a text for a basic course in management, it will be interesting to industrial engineers because of its excellent presentation of management as the unifying influence in the operation and control of an organized activity. The author starts with the fundamental concepts of management philosophy and activity and develops a balanced view of the relation of line and staff activities to the management function. Charts, diagrams and pictures help the reader. I find the case studies interesting even though they are intended for classroom use. Prof. Terry is to be complimented for the absence of dogma and verbiage so common in writings on management. He seems to feel, as I do, that organizations must be run by men making use of principles and not by principles alone.

# Time Study and Labor Relations[1]

By Harold O. Davidson

Assistant Professor of Industrial Engineering and Research Associate, The Ohio State University. Chairman, Technical Committee on Work Measurement.—AIIE.

There is probably no area of management wherein the influence of Industrial Engineering on labor relations is more direct and the extra-technical factors less clearly appreciated than the area of time study. The Industrial Engineer's matter of concern in this area has for the most part been the technological problems such as rating, allowances, and so forth. The concern of the employee and his union, however, has been less with the technology than with the doctrine which governs its application. This is not to say that the employee has no interest in a better technology of time study, or that the development of better techniques is not a major task for the Industrial Engineering profession. However, those who envision a solution of the basic problems through the instrumentality of technology alone should take note that the great failures in the field of time study can be traced primarily to doctrinal rather than technological factors, inadequate as the technology may have been by our present or projected standards. The development and examination of this thesis—that the great failures of time study have been doctrinal—will be a primary purpose of this paper since, in our opinion, it is of fundamental importance in defining the role of the Industrial Engineer in the field of time study. This in turn is a major determinant of the way in which his actions will affect labor relations.

By virtue of special knowledge and experience, and the possession of special techniques, the Industrial Engineer in time study occupies the position of an expert. In general, a professional relationship between expert and client is a two-party affair in which the expert offers advice or proffers services relevant to the person, property, or affairs of the client, which the client may either accept or reject. This is the case in medicine, in law, and in most engineering work. The time study expert, however, usually finds himself in a situation wherein his recommendations and services apply not to the client, but to a third party — the employee. In practice, moreover, his value to the client has usually been measured not so much by the calibre or ethicality of professional service as by the extent to which the behavior of the third party is influenced as a result of his activities.

We find therefore that the time study practitioner is participant to a three-party relationship in which the other two parties, in so far as labor relations are concerned, are the principals. His role in that relationship, whether as an employee of management or fee consultant, has been predominately as an agent of management. Hence the doctrine which governs the application of time study will ordinarily be related quite closely to general management policy though it may also be influenced by the time study practitioner himself to the extent that as an expert he has a certain freedom of decision within his special field. It may also be influenced by restrictions imposed by government, by employees and their unions, and by professional groups through the establishment of standards for ethical practice.

The role of the time study practitioner in labor relations could well be the subject of an extensive sociological study. The foregoing remarks indicate nothing more than the fact that his position is inclined to be somewhat equivocal. It is in the resolution of this equivocality, we think, that the major failures in time study practice have occurred. In speaking of "failures" we are not, of course, referring to technical deficiencies (such as rating errors, etc.) but to impotence in dealing with basic human problems of our industrial society. For this reason we should examine the development and present state of time study from a perspective which also includes the development of organized labor and management. Particularly, we should note that throughout most of the period over which time study has developed organized labor was engaged in a campaign against management authoritarianism. If one desires, he may call it a struggle for the right to bargain collectively but it amounts to much the same thing. Against this background of evolution in the basic relationships of our industrial society any doctrine which attempted to establish the position of the time study practitioner with respect to the employee as one of vested authority could be counted upon to produce antagonism. More specifically, then, we propose to define the major mistakes in the field of time study as attempts to establish the position of the time study practitioner under doctrines of vested authority. These mistakes will be reviewed as a basis for understanding certain difficulties which we encounter in time study today. In this review we shall not be much concerned with how the matter might appear from the technical viewpoint of an Industrial Engineer. Rather, we are concerned with how the matter was regarded by the employee and his union which to us seems to be of much great importance when we talk about labor relations.

## AUTHORITY BY MANAGEMENT PREROGATIVE

The first of these great mistakes culminated conspicuously in the repudiation of the Taylor system by organized labor and the rejection of time study in the Appropriations Act of 1914. While we may look upon the Taylor system as a technical success in that it opened up the field of Industrial Engineering for development, it was a failure in terms of its fundamental goals. It would be well for us to recall, in those moments when we are inclined to look hopefully toward a foolproof rating or synthetic time system, that the failure of the Taylor system was social rather than technological in character. It was basically a failure of the doctrine of authority by management prerogative. The evidence for this conclusion may not be apparent in reviews of the Taylor system which treat of its technical features, but it is quite clear in Taylor's own writings, in the hearings of the Congressional Investigation of the Taylor system (1912), in the report of the Hoxie Investigation for the United States Commission on Industrial Relations (1914), and in a number of other papers.[2] There is not space to take up the case in detail but it may be useful to state Taylor's goal, strategic objectives, and tactics in outline form as they may be determined from a careful study of the sources mentioned:

1. Taylor's Goal
   Taylor's goal was expressed in a philosophy of management which sought to dissolve labor-management strife by creating a mutuality of interest. That philosophy may be characterised as:
   a. Materialistic — Taylor looked upon high productivity as the sole source for a mutuality of interest.
   b. Authoritarian—Taylor regarded management as the sole judge of what the employee's share should be and what he must do to earn it.
2. Taylor's Strategic Objectives
   a. Increase productive potential by improving planning, controls, and methods.
   b. Maximize realization of the potential through high production standards.
3. Taylor's Tactics
   a. Improve planning, controls, and methods.
   b. Use time study to determine maximum sustainable output rate of exceptional employees. This is taken as the standard time and constitutes the production goal which employees are to achieve.

[1] Based in part on a paper presented at the National Conference on **Industrial Engineering in Labor Relations** of the American Institute of Industrial Engineers at Cincinnati, Ohio, on April 30, 1953. The author expresses appreciation to members of that audience whose contributions in a discussion session following presentation of the original paper have assisted him in this effort.

[2] See: F. W. Taylor, **Scientific Management.** Harper and Brothers, New York, 1947. R. F. Hoxie, **Scientific Management and Labor.** D. Appleton and Co., New York, 1915.

c. Set allowed time at about 62½% of standard.

d. Establish production at the standard by enforcing strict compliance to the goal.

If it should appear that this summary presents an exaggerated view of Taylor's tactics one may verify it from Taylor's own writings. His report on the pig iron handling study will show quite clearly that his standard was a maximum sustainable output rate of exceptional employees. With respect to the 60% bonus at maximum production rate, Taylor had said:

"When they (the employees) receive much more than a 60 per cent increase in wages many of them will work irregularly and tend to become more or less shiftless, extravagant, and dissipated."

And with respect to enforcement of production standards one will find at various places in Taylor's works that he used rate cuts, fines, and layoffs as means of insuring compliance.

It is scarcely surprising that the time study practitioner in the Taylor system and its counterparts was resented by the employee. In all likelihood the time study man because of his close association with the employee often became a symbol of the entire system of management autocracy. The employee was no doubt dissatisfied in some measure with conditions of work during that period, but his bitter antagonism was aroused not so much by the conditions (for men have endured far worse) as by the management autocracy which imposed them under the self-righteous sanction of "management prerogative." It was this doctrine of authority by management prerogative which gave sanction to the tactics which Taylor employed. It was in this doctrine rather than in the specific tactics that we find the basic cause of the failure. The Taylor system did not achieve its founder's goal of resolving labor-management strife, and it proved incapable of eliciting the cooperation of employees in the realization of productive capacity (which other features of the system, it is true, successfully increased). It is somewhat ironical in view of Taylor's expressed distaste of labor-management strife that he could scarcely have designed a more efficient method for intensifying strife than his tactics of time study applications.

What we have just described is, of course, the failure of a general management doctrine which was only incidentally applied to time study. It was simply a misfortune that the early development of time study should have proceeded under such a doctrine. Nevertheless, the time study practitioner did become a symbol of that doctrine, a heritage of which those arriving later upon the scene have not always found it easy to divest themselves.

The Gilbreth's, in notable contrast to Taylor, appear to have concentrated their efforts on the strategy of increasing productive potential and did not seek recourse in autocratic methods for the enforcement of high productive standards. Still, the Taylor system and its counterparts had achieved such wide notoriety that their repudiation by organized labor affected the entire field of time study.

There is evidence that at least some executives recognized the fundamental weakness of the Taylor system. In 1917 Harlow S. Person authored a paper entitled "The Manager, the Worker, and the Social Scientist" (Bulletin of the Taylor Society, February, 1917) which contained, though perhaps in rudimentary form, some of the ideas which received great acclaim in the later writings of Elton Mayo. Person's insight and perspective must be judged the more remarkable in view of his close association with Taylor as a President and Managing Director of the Taylor Society.

By this time, however, time study had emerged as a specialized field and had passed into the hands of a group of time study specialists. Some of them, no doubt, were also aware of the basic causes of the Taylor system's demise. Others quite obviously were not, and they committed the second great mistake to affect the field of time study by promulgating the doctrine of authority by superior wisdom. Again, while the doctrine was not promoted by all time study practitioners it was sufficiently widespread to affect the entire field.

## AUTHORITY OF SUPERIOR WISDOM

Whereas the time study practitioner in the Taylor system gained authority for his position as an agent under the doctrine of management prerogative, the doctrine of superior wisdom sought to convey authority by virtue of the technological wisdom which the practitioner purveyed. It approached in essence the authority of a cult, the members of which are presumed to possess wisdom in special matters beyond that of ordinary men and whose fitness to judge in such matters therefore surpasses that of ordinary men.

The appeal for authority of superior wisdom is implicit in allusions to a "science" of time study; or, as one author put it, "the pure science . . . of accurate time study." It has been rather typical, however, of those who pursued this doctrine that they exhibited hostility and uncooperativeness when persons having some measure of scientific competence attempted to examine their methodology. While claiming scientific validity, it is true that few if any of them actually denied the necessity of considerable judgment on the part of the practitioner. Their position appears to have been that this judgment was of such a high order of expertness that its validity could not rightly be assailed.

The motives for asserting the authority of superior wisdom cannot be easily or certainly defined. Quite certainly they varied among different individuals. In some cases perhaps it was a deliberately calculated false front which was employed for its usefulness in selling one's services to a client, impressing an employer, or suppressing employee objections. In others it may well have been motivated by an unconscious desire for the prestige which one seems to obtain if he can associate the word "science" with his activities. In still others it may be accounted for as merely the uncritical repetition of what others had said and done.

The myth of scientific time study was, of course, punctured by Ralph Presgrave (though there were others who, as we have said before, never supported it) and then was thoroughly riddled by William Gomberg, in works that are among the important contributions to the field. Presgrave's purpose seems mainly to have been the dispersal of fog which had accumulated about the subject from much of the technical writing which had appeared up to the date of his writing. While extending Presgrave's work, Gomberg also appears to have intended a major blow in behalf of the unions at the doctrine of superior wisdom as representing a form of authoritarianism incompatible with the principle of collective bargaining. The point of this is that while the "scientific time study" chatter may now be nothing more than a source of personal amusement to the competent Industrial Engineer, the employee and his union regard it as a serious matter. What assurance had he that the next time study practitioner he encountered might not be one of the "cult"?

Both of the doctrines which we have discussed have one point in common. They attempted to establish in the position of the time study practitioner a degree of authority incompatible with the collective bargaining relationship between labor and management which was evolving over essentially the same period that these doctrines were applied. Once this idea is appreciated the opposition of unions to the recent proposal to the American Standards Association for establishment of "a project designed to establish standards in the field of predetermined motion times" [3] can be easily understood, and failure of the proposal might have been predicted with a fair degree of assurance. From the union viewpoint there was implicit in that proposal another form of authoritarian doctrine, which we might term the doctrine of pre-eminent endorsement. Without classifying the matter as a critical error, it may still be useful to examine the way in which an authoritarian doctrine might be implied by the proposal.

Before proceeding, it should be clearly understood that we do not impute to the framers of the proposal which was made to the ASA any deliberate or even unconscious designs for conferring authority upon themselves and other time study practitioners by that action. It seems entirely possible that the proposal was framed from a limited technical perspective, such that the manifestation of union opposition was a quite genuine surprise. Be

(Continued on Page 10)

[3] Proposal considered and rejected at a General Conference of the American Standards Association, Jan. 23, 1953, at which the author was present as a representative of the AIIE.

# The Industrial Engineering Audit

By Harold R. Nissley, P.E.
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Based on a talk given at one of the Management Institutes at the University of Wisconsin, April, 1953.

## WHAT IS AN INDUSTRIAL ENGINEERING AUDIT?

The industrial engineering audit is similar in many respects to the periodic financial audit. Like the financial audit, the industrial engineering audit tells three things: (a) Where you have been; (b) where you are; and (c) where you are headed — with suggestions for changing your course, if you are headed in the wrong direction.

Industrial engineering audits are of two kinds: (1) The audit that compares a company's factory, office, or warehousing efficiency with similar operations elsewhere. (2) The audit that indicates the efficiency of an industrial engineering department. This latter audit could result in a reduction in the time taken to set standards; it could increase the consistency of standards and thus decrease the time spent in rate challenges; it might point the way to straightening out an incongruous earnings structure.

Like the financial audit, the industrial engineering audit is best done by outside professional talent (a) so as to bring as much objectivity as possible to bear on techniques and results; (b) to introduce new and better techniques; and (c) to gain wider and quicker acceptability of new ideas. Unfortunately professional audits too often are relied on only after rigor mortis has set in on an industrial operation. Unfortunately, too, many plant industrial engineers resent an outside appraisal of their efforts instead of inviting periodic audits of their work.

## PREPARATION FOR THE AUDIT

Before the start of a successful audit several steps should be taken. Assuming top management feels the real need for such an audit all parties to the audit should be properly informed; this intention to have an audit made of the industrial engineering activity should be expressed with some finesse. Top level thinking should be crystallized in a written statement of purposes of the audit. Supervisory checks should be made to gage the size of the problem. Finally the investigation and subsequent report and recommendations are made to the interested parties (again top management).

*Step number one* is to crystallize in writing the purpose(s) of the industrial engineering audit. Some statement as the following might be used in focusing attention on the objective(s) of the audit:

(a) To find out if an industrial engineering problem exists at X Company.
(b) If one does exist, what is its size?
(c) What can be done to solve it?

*Step number two* is to inform all interested parties that such an audit will be undertaken.

*Step number three* is to collect the data (after deciding what data are necessary to measure the problem and the current method of handling it).

*Step number four* is the summary and conclusions (and recommendations) — the written and verbal report.

## WHAT'S THE BEST WAY TO INFORM THE INTERESTED PARTIES?

There are several ways of informing the interested parties — after deciding who these interested parties are. Certainly the first set of interested parties will be the plant industrial engineers themselves. The second set of interested parties will probably be the supervisors.

The decision to have an audit should be told to the industrial engineering department after the chief industrial engineer, himself, has been informed. He in turn may tell his staff; or he may choose to call his staff together and let the works manager discuss it with them. Whichever method is employed, the works manager will have a much stronger support for such an audit, if he can assure everyone that no one will suffer any financial loss as a result of this audit. A sincere works manager, however, might point out that there may be some shifting of personnel to take full advantage of each person's capabilities. And certainly he would expect such an audit to yield suggestions for improvements in the present method of setting and selling standards — "improvements that will not only make all our jobs easier but add to the prestige of the I. E. Department."

The second group of interested people are the supervisors. In a small organization employing fewer than 10 supervisors, the decision to have an industrial engineering audit made might be made known by calling all supervisors together and telling them (preferably in the presence of the chief industrial engineer). Where the number of supervisors exceeds 10 and especially in multi-shift operations, it probably would be more expedient to send a memorandum similar to the following:

To All Supervisors of X Company:

Mr. Phil Presquick, a Professional Engineer from Pittsfield, will be spending a few days with our Industrial Engineering Department. As banks are examined and companies are audited periodically, we are asking Mr. Presquick to do an auditing job on our Industrial Engineering Department in the hope that he can provide constructive criticism for improvement. He is not here to condemn anything or anyone.

So that he might do an intelligent appraisal job of our industrial engineering activity, he will want to talk to you, the "Consumer," of that activity. Will you, therefore, spend from 10 to 30 minutes with him when he calls on you and discuss with him those industrial engineering areas where you think we are strong and anywhere we might improve ourselves

Thank you for your cooperation.

John Wilson, Works Manager

## COLLECTING THE DATA

Several types of data are necessary to appraise the effectiveness of an industrial engineering activity. One kind is the subjective opinion of supervisors — their reaction to the present "industrial engineering set-up and their ideas for possible improvement." To gain a good cross section of opinion between 10 and 20 supervisors or other key personnel should be interviewed for 15 to 30 minutes. Sound interviewing techniques should be employed: Leading questions obviously should be avoided; positive thinking should be encouraged; personalities should be minimized; the interviewer should limit himself to mental notes (not written ones) during the interview, and, of course, no one should be quoted.

A second class of data is that involving knowledge of the field — "book learning" for want of a better expression. This information may best be obtained from written tests taken by members of the industrial engineering department. Again, anonymity of test results should be maintained; indeed, it is well to gain top management's consent to keep these individual test results secret — known only to the person conducting the audit. There are several reasons for this; when critically analysed the advantages of such secrecy seem to out-weigh the disadvantages.

Sample questions from this "technical knowledge" phase of the audit might be:

1. A 25% saving in time will yield how much more production? _____
2. Given: 0.8 inch feed/minute; 60 rpm. Find feed/revolution. _____
3. If it takes 0.0021 minutes to transport a one ounce weight 10 inches, how much time will it take to transport it 5 inches? _____
4. To insure good support to an operator's back, the radius of curvature of a chair rest should be: 8"; 10"; 12"; 14"; 16"; 18". (Circle your answer.)
5. You could expect a 20%, 40%, 60%, 80% reduction in the time required to thread a needle with black thread against a black background, if you substituted a white background in this seeing task. (Circle your answer.)

A third class of data might be classed as "Application ability" — the ability of an observer or analyst to apply the knowledge he possesses. Both written and visual tests may be developed for this third class. The written portion of this "application" phase might include such questions as:

1. If you had a group of incentive operators who had acquired fair skill in using a poor method (e. g. two finger typing), what would be your procedure to win them over to your method (e. g. touch typing using all ten fingers)? Note: You are convinced the new method will carry a lower piece rate but will yield from 3 to 5 per cent more take-home pay; the new method will yield from 30 to 50 per cent more production.
2. How do you determine when you have enough time study data to leave an operator? In other words what rules or checks do you apply so that you feel satisfied that you have enough data without unduly prolonging your production floor study?
3. Incentive creepage plagues many piece work shops today. If you were employed in a union shop whose rate structure had gone wild, how would you attempt to straighten it out

(or would you give it up as hopeless)?

4. Given a rated cycle time of one minute and total allowance of 20%. What is the mathematically correct number of pieces a normal operator should turn out in a 60 minute period?
5. Given an array of time study data on an observation sheet: 0.17; 0.14; 0.19; 0.12; 0.17; 0.16; 0.13; 0.10; 0.15; 013; 0.18; 0.14; 0.17; 0.13; 0.14; 0.15. What statistical technique would you employ on the production floor to get a quick and fairly reliable average (arithmetic, median, or modal)?

But sound industrial engineering practice is something more than written answers to theoretical and practical questions. A good industrial engineer should (a) know how to read a stop watch and (b) he should be able to judge pace. Reading a stop watch accurately may be taken for granted. Again, an auditor should take nothing for granted. The need for including stop watch reading in an industrial engineering audit was recently called to the writer's attention when he observed a 20 per cent variation between the low and high observations on a 0.30 minute cycle job when testing 15 industrial engineers (only five of whom read their watches correctly to the second significant place); this part of the audit was repeated 20 times so that each observer had 20 opportunities of observing and recording the elemental and cyclical times (no rating was included in this part of the test.

Judging speed or pace is another important industrial engineering skill that should be measured. This is best done by judging the skill and effort of operators performing regular jobs. Film loops of such jobs or similar ones can be run at different speeds after a group "normal" has been established. A calibrated rheostat on the projector can be used to indicate the true variations in projector speed (hence speed of operator performance) as the projector is varied. Thus group estimates compared with true operator performance at various speeds may be plotted and mean deviations and other statistics derived. There are, of course, other methods of judging pace (e. g. card dealing, walking, SAM and Phil Carroll rating films—even your own jobs out on the production floor).

### WORK SIMPLIFICATION PHASE OF INVESTIGATION

So far attention has been directed to measuring the time study knowledge and skill of an industrial engineering department. Unfortunately too much time has been spent on time study and too little on making jobs easier and more productive. An alert time study observer has an excellent opportunity of detecting short cuts in a job — if he uses his imagination along with his time study knowledge and skill. Again, there are several ways of testing this work simplification imagination of a group of industrial engineers. One of these is by written test. Another is by verbal test with the use of "before-and-after" shop movies.

Sample test questions below illustrate the first of these:

1. The standard typewriter keyboard was designed with the finger load distribution in mind. True: ———. False: ———.
2. Smooth, round screwdriver handles are faster and less fatiguing for medium or heavy work than rough semi-flat handles. True: ———. False: ———.
3. Alternate standing and sitting at most assembly jobs is less fatiguing than continuous sitting. True: ———. False: ———.
4. Because the straight line is the shortest distance between two points, straight-line motions should be employed in short cycle work. True: ———. False: ———.
5. The two hands should begin as well as complete their motions at the same instant wherever practical. True: ———. False: ———.

Although shop movies are best for bringing our job improvement suggestions other means may be used, too. A trip through your own shop with special attention to 10 jobs would provide good test material; each testee is asked to list the job improvement possibilities (and estimated costs and savings).

### REPORT

Like other engineering reports, the industrial engineering report should contain the following:

1. Purpose.
2. Conclusions: (a) Time study knowledge and skill possessed by local industrial engineers. (b) Work simplification knowledge and skill possessed by local engineers. (c) Areas of possible improvement.
3. Recommendations.
4. Method and procedure.
5. Statistics and summaries of tests (without identification).

### POSSIBLE GAINS FROM AN INDUSTRIAL ENGINEERING AUDIT

An audit such as that just outlined will take from 5 to 10 days of professional investigation: collecting data, analysing these data, and writing and submitting the final report. It will impose a 30 to 90 man-hour obligation on the part of the company for interviewing and testing purposes. Like other techniques, the cost of such an audit in time and money should be matched with the gain.

Three important groups of people should gain from an intelligently conducted industrial engineering audit: (1) The supervisors; (2) the operators; and (3) the local industrial engineers. And the company should gain, of course, to the degree that any or all of these groups gain.

If the audit points the way to easier and better jobs and lower unit costs; if the audit suggests faster and more accurate methods of setting and selling standards; if the audit yields quicker and happier ways of effecting a "meeting of the minds" — then all three of these groups gain. And the company gains, too.

## Management's Responsibility For Cost Reduction

(Continued from Page 3)

splurge. Everybody "gets in the act." And for a while, there is enthusiasm and we make some real improvements. Note however, there is no goal and consequently, there is no follow up.

Usually, the management gets back the money it spent. So the venture was profitable. The inevitable has been put off a while longer. But wouldn't it be better management to go after 10 per cent say? And keep the heat on 'till the goal was reached? Then set a goal for next year and go after that just as strenously?

My idea of cost control is the steady, planned, day-after-day, grinding down of the cost, whatever it is. This is management's responsibility. Management must continue to make progress. Therefore, management must set the goals. They must develop people who can attain those goals and, I believe, provide the incentives that reward those who get results.

## TIME STUDY AND LABOR RELATIONS[1]

(Continued from Page 8)

that as it may, the opposition did develop and its basis may perhaps be surmised.

It may be taken as a fact that any standards issued by the American Standards Association carry with them a preponderant authority due to the pre-eminence of that body. This suggests what we mean by pre-eminent endorsement. Any person or group market with high prestige may transfer some degree of that prestige by endorsement. This is a well-known characteristic of our culture and even appears to apply when the endorser has no knowledge at all of what he endorses.

Professional groups which have attained this sort of prestige, however, have done so by maintaining the highest standards of objectivity. It would not necessarily follow if a project on synthetic time systems were initiated under ASA auspices that a set of ASA Standards would be established. Negative results could be expected to terminate such a project. However, the project might extend over a considerable period of time and the prestige of the ASA is sufficient so that in the meantime the mere sponsorship of the project by that organization might imply endorsement of synthetic time systems in principle.

Briefly, then, this was how the union representatives appeared to view the situation. They envisioned the possibility of a new form of authoritarian doctrine in conflict with the principle of collective bargaining. While this is a point on which employees and their representatives are apt to be quite sensitive, it is also one of which Industrial Engineers have too often been notably insensitive.

In conclusion, there is but one fundamental premise which this discussion has sought to establish. It is simply that an attempt to apply time study procedures under any form of authoritarian doctrine, in an industrial society based on the collective bargaining relationship, must necessarily fail.

Therefore, if the role of the Industrial Engineer in time study is to be solely that of management's agent he must employ means of discharging the duties of his agency which are in consonance with the basic collective bargaining relationship. And if, as might sometime be more generally the case, he is to function as an impartial expert serving both management and labor, then his services are completed with the submission of his recommendation which the parties may then do with as they choose.

# A MISSING INGREDIENT

**By Wilbur R. Meredith**

Associate Professor of Engineering Administration, Case Institute of Technology.

Industrial Engineering improvements have resulted in great material benefits with attendant social progress. Frederick W. Taylor, the Moses of the industrial engineering fraternity, supplied the "scientific method" as a road map to chart a course to the promised land of industrial efficiency. That was many years ago. Having come a long way, it often happens that the promised land still seems remote. Why? May it not be that pre-occupation with "*the* scientific method" engenders an unwarranted confidence in its practitioners?

Marching down the corridors of time, the familiar landmarks of the engineering approach to problem-solving begin to blur — quantitative analysis, experimentation and objective attitudes — the reliable, concrete, reassuring "scientific" techniques lose some of their magic touch.

There are few applied scientists who have not experienced serious feelings of futility when hard-won solutions of technical problems are modified or swept aside by union negotiation or management decision. Further, the aggressive defense of such solutions often fans a flame of animosity in the beneficiaries of engineering skill. It cannot be repeated too frequently that the missing ingredient is adequate consideration of the human element.

Why should so many technicians fail — not for lack of technological ability — but through failure to get acceptance for their ideas?

To begin with, the engineer is a kind of orphan in the industrial world. Experimentally minded to more than an average degree, he has high intellectual curiosity and integrity. Change is readily accepted by him as a part of the natural law.

Unfortunately much of the industrial population finds it necessary to resist new methods, new equipment, and new products as a threat to personal security. Whereas the engineer makes his living by devising new and better ways of doing things, the production worker has a heavy investment in the status quo. The years of practice and study that have gone into the development of a well-paid skill can be wiped out overnight by the fulfillment of an engineer's dream of mechanization.

Space does not here permit an examination of the difficulties raised by this conflict but it may be said that the engineer's devotion to his profession and his personal integrity hinder his ability to accept technical compromises which must be made in deference to the personal needs of individuals. This in turn slows rather than speeds the rate of technological progress and in many cases has resulted in the status quo being maintained where it should not have been.

In the second place the professional man is trained to think and act logically. Facts are his forte. He is likely to view things in the light of their being true or false — fact or fancy. The production worker, on the other hand, not having comparable mental equipment and training in logical thinking is much inclined to react to situations intuitively. Intuitions thus far have not responded to logical analysis.

It is in this area that "*The* scientific method" meets its greatest difficulty. When an attempt is made to get worker acceptance of the one best method of doing a job, it may be met with an intuitional road-block. When the worker says he doesn't believe the new method will work, what he really means is that he does not see how it will work to his benefit. It isn't a question of the engineering facts of the matter.

At this point the applied scientist makes use of his natural inclinations and training. He marshals his facts and figures in logical order to prove his technical competence. The better he presents his case, the more resistance he meets. Actually he is arguing the wrong issue; unless and until the workman can be shown that he, personally, will benefit his cooperation cannot be gained. Many managements have learned to their sorrow that force may be of little use in effecting improvements since organized labor places tremendous power behind individuals.

Briefly stated, the industrial engineer by nature and training has an orderly, inquiring mind and a creative attitude which he uses primarily to effect changes in things and ideas. While thus pre-occupied he affects people beneficially in the long run, but perhaps adversely at first. This initial impact of his activities brings him into conflict with a wide variety of people who resent his efforts. How may this conflict be ameliorated?

A more detailed analysis of the general problem may be helpful. Mutual understanding and the harmonious pursuit of a common goal is essentially what is being sought.

Responsibility for taking the initiative in this process rests with the engineer since he is the one who proposes a modification of existing relationships.

First, let him realize and admit to himself that he is probably more proficient in dealing with things and ideas than with people. (That's one reason he is an engineer rather than, for example, a salesman.) Let him govern himself accordingly and budget ample time for devising means of "selling" his engineering skill to those who must have his help. The world may beat a path to the door of the better mouse-trap builder, but it constructs superhighways to the doors of a lot of mouse-trap builders with neon signs.

The line supervisor is a key customer of the industrial engineer. He can do much to smooth the way for personal acceptance of the engineer and his plans. Therefore a knowledge and understanding of his point of view — his likes and dislikes — is needed.

In the beginning an attitude of watchful waiting or covert hostility is to be expected. The staff specialist invades the private domain of the supervisor ostensibly to help him. Here is a definite implication that the supervisor *needs* help; it tends to lower his prestige and to put his defensive mechanisms in high gear.

His prestige being under attack, he may be counted upon to take the offense in showing his subordinates — and his superiors — that he is still the last word on all subjects within his sphere of operation. And he can be really offensive when he tries!

The reaction stems basically from a feeling of insecurity which causes a tender sensitivity to the implication that help is needed. The engineer must respond to such aggression with patience, understanding, and restraint. His own emotions must be controlled if the supervisor's deficiencies are to be turned to advantage as they can be.

If the line employee feels the need for more prestige, it should be given him by asking for his help. He will then tell others what a fine job is being done because he has made helpful suggestions which are put to use. His contributions give him a vested interest in the success of a project; he will attempt to assure its effectiveness because in some measure its success becomes his own.[1]

The prime requisite of cooperative effort is that the parties shall have a common goal. In the case under discussion the common goal of line and staff alike is increased production. A statement of this kind is so broad that it is almost but not quite meaningless. It has one important advantage; it provides a starting point of agreement between the parties.

Characteristically, as two or more people start from a general point of agreement and proceed toward consideration of more and more specific minutae, they will finally arrive at the point where honest difference of opinion is encountered. Patience, forbearance, and a willingness to compromise delay the stalemate and permit maximum progress to be made.

All too frequently it is at this point of stalemate that uncontrolled emotions flare in a manner precluding future cooperation; great loss results.

[1] There is some popular thinking that acceptance for one's ideas is best secured by leading another person to believe the idea is really his own. This is wrong. Such lack of integrity and insulting of another's intelligence will, in the long run, boomerang.

The facts in the matter are that, if the suggested next step is not clear enough for well-informed cooperative people to agree upon it, the step should not be taken.

Should neither party resort to "authority" to forward his own convictions, a lasting personal relationship can be established. Further progress after time as a process has had a chance to work its miracles will be assured.

Another source of friction is the failure of staff employees to give sincere full credit for assistance received from operative employees and their supervisors. On the other hand, everyone up and down the line is encouraged and inspired by valid reports of mutual aid which has been generated by acknowledged respect of line and staff employees for each other. Such reports are welcome relief from the old theme song, "He had everything all fouled up but *I* straightened him out."

In addition to fearing loss of prestige through the activities of "glory-grabbers," the supervisor often has occasion to wonder just what kind of "reports" are being made in mahogany row about him, personally, and the personnel he supervises. Still they might be embarrassing or difficult to explain. Therefore, the line employee may well be worried that he has an informer at his elbow in the presence of a staff engineer. Perhaps he has — even if an innocent one!

Like the wise old owl, the engineer who gains the confidence of rank-and-file associates and their immediate supervisors will follow the maxim, "The more he saw, the less he spoke; the less he spoke, the more he heard . . ." He should confine his attention to the solving of the problems to which he is assigned and restrict his comments on any administrative problems which may come to his attention while he is in the shop.

The new or young engineer should reserve his own judgment about plant conditions and practices until he is fully informed as to why they are as they are. Many sound working arrangements are not those that would receive the approval of leading authors on the subject; however, they may be the best available at a particular time and place. In connection with this, there is another important consideration.

The engineer with his fertile imagination, energy, and drive — all sound personal qualities in an industrial engineer — may easily have a tendency to pile change upon change at a rate that just doesn't permit assimilation by those who must make extensive adjustments to them.

A standing joke among the employees of one company suffering from an invasion of consulting engineers was that "I went to get a drink of water and while I was gone I missed two 'systems.'" Eventually that consulting firm lost a good account for no other reason than excessive change. The engineering was good — the many changes had intrinsic merit — but none of them was allowed to remain in effect long enough for its value to become apparent.

In a broader sense the engineering was bad, since efficiency fell off and stayed off during the period described above.

Why did a first-class consulting firm allow this to happen? Was it lack of skill or knowledge? No. What then? Members of the firm made the simple mistake of responding to pressure from top-management to get results faster than the facts in the situation permitted. With each additional application of pressure the firm came up with a new idea guaranteed to work.

To stand one's ground with the boss and insist that a reasonable amount of time must be allowed for the assimilation of one change before instituting an improvement on the change takes courage. It should be exercised. The supervisors and the operative employees will put their confidence in a man who will run the risks of top-management censure in order to give them a reasonable chance to adjust to the changes. Further, they will do their best to protect him by cooperating thoroughly with his plans.

It was suggested above that judgment should be reserved on conditions which obviously could be improved. (The reason being that no final judgment should ever be reached until conditions compel the moment of decision. It is only at this time that the latest information is available.) It has *not* been suggested that such conditions be ignored. To the contrary, why shouldn't a practice be made of preparing written notes on these conditions as they are observed? Such notes can be developed outside regular working hours and during the occasional times when a regular assignment cannot be carried forward for one reason or another. There need be no hurry to crystallize solutions from these notes.

If presented to the chief executive when his attention is centered on other matters, they will not get the careful examination they may merit. On the other hand, the time will come when executive attention will be directed to the poor conditions noted. Timing is of the essence. One should be ready for the opportunity, armed with study, knowledge of the facts, and forethought. A good idea ought not perish for want of proper presentation.

In summary let us say like David Harum, "There's as much human nature in some folks as there is in others, perhaps more."

Rank-and-file employees, union representatives, and minor supervisors are not the only people who resist innovation. The boss tends to keep on thinking about the problems *he* has under consideration.

More engineering time can profitably be assigned to consideration of the human elements even though it means sacrificing something from the technical or financial viewpoint.

The undesirable side effects of changing conditions may be modified by starting with a generalized objective to which all members of the team can give their cooperation. It may be expected that honest disagreements will arise which will require conciliation, compromise, good-will and a large measure of patience.

The staff employee should reconcile himself to being always under suspicion His every word and deed should be carefully scanned to make certain that it in no way betrays the confidence of his associates.

Further, under certain circumstances he may be obliged to place his own future in jeopardy in order to purchase time for employees to adjust themselves to changes which he, himself, may have innovated.

Technical engineering decisions must be made in a climate of conflicting personal interests. The area of conflict may be reduced by reserving judgment and delaying decision until the last possible moment. Then *at the right time*, let the die be cast and let the engineering facts speak for themselves.

## Book Review

*"Design of Machine Elements,"*
by M. F. Spotts,
Prentice-Hall, Inc.,
New York, 1953, 504 pages, $9.65
— by Robert M. Eastman, Associate Professor of Industrial Engineering, Georgia Institute of Technology

Prof. Spotts has done a good job with a difficult topic. By liberal use of diagrams, illustrations, examples and tables, he reduces the fog which surrounds machine design in most industrial engineering minds. The book is well organized and written.

However, most industrial engineers will find that a standard handbook in tool engineering or mechanical engineering will furnish necessary information on machines and machine elements. Also, many IE's are in companies where consultation with other staff experts is the quickest solution to the problem.

## Book Review

*"Industrial Electronic Engineering"*
by W. L. Davis and H. R. Weed,
Prentice-Hall, Inc.,
New York, 1953, 514 pages, $11.35
*"Electronic Engineering Principles"*
by John D. Ryder,
Prentice-Hall, Inc.,
New York, 1952, 505 pages, $9.00
— by Robert M. Eastman, Associate Professor of Industrial Engineering, Georgia Institute of Technology

When I read the advance descriptions of these volumes, I thought they might be the long-awaited works on electronic engineering which would be really understandable to the average industrial engineer. Unfortunately, they are primarily for electrical engineers and others with more background in math, circuits and electronics than the average IE has. Perhaps we are asking the impossible in expecting descriptions of highly technical subjects which will be easily understood and adequate for an industrial engineer.

Both volumes are excellent in their presentation of the subject, but both will be above most IE's. Davis and Weed put their emphasis on practical industrial uses, while Ryder discusses more of the theory involved.

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# Systems—
# The New Field for Industrial Engineering

By Alan J. Levy

Industrial Engineer, Bulova Watch Co.

Approximately 6 million employees, some 10% of the nations workers are engaged in the clerical activities of modern business.[1] This is an awesome number. The tremendous growth of this white collar group, which operates the systems now directing and controlling all business and manufacturing, has created serious and complex organizational problems. This is true not only in the production control, purchasing, inventory, personnel, research, and cost accounting departments of manufacturing companies but in every other type of institutional and governmental organization in America today. Systematic and intelligent research into the fundamental problem of systems has now become a major necessity for improving the efficiency of modern business organizations. The rapid growth in the output and sales of the business machine and office equipment industries; the increase in the number of management consultants — many of whom devote a great part of their time to systems work; and the creation of methods and systems departments in many of the larger corporations, all reflect the expansion in this field.

The system is the formal network of communication through which an organization functions; it is the apparatus of paper work and equipment that allows intelligence, information and direction to be carried through a business firm. This includes the whole company or any major department such as sales, production, purchasing — whatever it may be, there is some system present. The system itself is composed of a number of operational procedures and methods for which it is the "network of related procedures developed according to an integrated scheme for performing a major activity of the business."[2] It is created and changed purposefully (even if for wrong reasons) and the overall productivity as well as the limit of efficiency of an organization depends on the system. It is not necessary to belabor this point, for systems pervade all organized activity, and the problem of their design, adaptation, and operation confronts everyone in a position of authority. Thus systems meet the two basic requirements for engaging the attention of the profession of industrial engineering; systems represent something fundamental and they are an actual concern in industrial life.

To fully develop the new role for the industrial engineer in systems work it is necessary to quickly review the growth in size of administrative personnel in industry and describe systems work as it exists today. During the last fifty years, manufacturing firms in the United States have allocated increasing resources to the administrative functions of business; from 1899 to 1947 the administrative personnel per hundred persons on the production staff increased from 9.9% to 22.2%.[3] This is the result of the greater complexity and increased productivity of industrial life and represents a basic change in the structure and character of production. For today it is the organization rather than the individual that is productive: it is the integration of individual effort into a pattern that resulted in the spectacular increase in production over the last half century. As an example, the high speed, heavy tonnage operation of a mill depends not only on the large capital investment, but on the large administrative staff which plans, supervises, coordinates, and controls the activities with records, reports and business memos. It is the pattern, the operating system, that is vital and thus the efficiency of the system is of utmost importance. Improvements in systems represent more than savings in clerical labor, they represent basic changes in the total effectiveness of the enterprise. Furthermore, the growth in the size and scope of government has required additional personnel to prepare the tax returns and information that comply with special government regulations — information virtually all manufacturing firms must supply today. Here again an intelligent and efficient system must be devised to collect and tabulate the necessary information.

That administrative costs have increased and that an intelligently designed, easily operated system is important is generally recognized. Management is constantly confronted with its paper work, the clerical personnel and the occasional exasperating break down in a system. Office equipment and business machine manufacturers have greatly increased both the production and the variety of their goods — in many cases turning out machines capable of extraordinary performance. Many of these manufacturers employ full-time "systems salesmen." Systems problems as such have already lead to the formation of a professional group, Systems and Procedures Association of America,[4] and there are methods departments in many large organizations. Business and trade magazines have emphasized the systems problem with many articles publicizing techniques to overcome costly office procedure. Despite all this activity, systems work is generally performed hodge-podge in most organizations so that the average system is like Topsy, it just growed. The system is usually created under conditions of stress as an annoying necessity, generally not thought out in detail, and very often it is designed by a salesman who is selling a particular piece of equipment. The challenges offered by this large area of systems can best be met by industrial engineers for three principal reasons: the methodology already employed is primarily industrial engineering techniques: there is a need for new analytic tools in studying systems; and the perspective needed in systems work requires an I.E. approach.

The techniques used today in systems work are basically methods studies and adaptations of methods work. All the old I.E. tools are put to work, often dressed up in attractive boxes and kits or presented in multicolored pamphlets and magazine articles. Clerical work is viewed as just one more productive operation and attacked with the work simplification techniques so successfully used in repetitive labor, blind filling gives way to use of visible trays, multiple typings are replaced by a ditto machine for faster and neater work. The individual forms are studied and unnecessary operations, duplications or misinformation are eliminated. A more reliable inventory control is added. An office layout is prepared using a magnetic board and a light meter determines the optimum illumination for each desk. All of this of course is for the good. The faster recording, filing, storing and using of records has produced a substantial increase in the productivity and efficiency of clerical operations with reductions in costs. It is encouraging that many people are now using these methods in solving their problems, but industrial engineering techniques can be used to the greatest advantage by members of the profession.

The techniques now in general use are of only limited value, for good analytic tools are still generally not available. Present methods are principally pictorial and graphic, whereas they should be statistical and mathematical. To illustrate, a flow process chart is simple to make and often gives a neat picture of the total number of operations, the distance moved, the delays in movement and the burdensome handling of material by hand operations. Based on such a chart, reductions in each of these figures may take place. But we may require a fourth-dimension model of the flow process chart to study a complicated, many copied continuous form. Systems studies should be based on the recent findings in such a field as communication theory and analytic tools should be used to study the capacity of the communication

channel, the coding process that may be used, or the effect of noise. For a system basically is the recording and transmitting of intelligence, and though the physical distance travelled by a form should be short, the entropy, (adapting Shannon's terminology) [5] should be low. Thus, systems work should recognize that communication exists on three levels: technical, semantic and influential. While electrical engineers will develop the technical aspect, industrial engineers should begin to study and apply the ideas of semantics, that is the interpretation of meaning by the receiver as compared with the intended meaning of the sender; and also consider the influential level of communication, that is the effectiveness of a message in leading to desired conduct. The communication theory is only one of a number of basic studies coming from the social and physical sciences, and is cited to indicate some of the new developments that have taken place. Engineering has always been an applied science and it is the duty of the industrial engineer to study these findings and apply the pertinent material in operating situations. It is from the original pioneer work in scientific management that the profession of industrial engineering grew and the tools for the systematic study of factory problems came into use. The profession must now develop new tools for modern organizational problems.

While the use and development of a good set of tools is important, the perspective is still more important. In preparing a methods study of a worker placing tubes in a radio chassis it is academic to ask whether the operation is necessary or whether it is meaningful. Without tubes the radio won't play, but without a given piece of information or a particular form an operation will not necessarily shut down. Systems work must be viewed, as it already is by many, as an over-all problem; it is more than the sum of its parts, more than the flow of the paper and the total number of individual operations. Involved in systems work are all the policies of a company, all the considerations that go into management — a generalist point of view. Only the industrial engineer has the combined technical, business, organizational, production, accounting and statistical background needed for systems work. The industrial engineer stresses the top management approach. This approach, which is crucial in systems work, is generally not applied today because many systems people have tied their minds to a unit operation and a work flow perspective. The work must be organized according to an overall objective that takes into account the basic information that must be recorded and used, the signalling apparatus required, and the desired controls included. Industrial engineers can enlarge the application of the top management approach to systems work today.

As systems work represents unparalleled possibilities in improving the effectiveness of modern organizations, training in systems and procedures should be included in the industrial engineering curriculums now offered at different universities.[6] Many of the courses now available to the industrial engineering student directly or indirectly develop or stress systems. The present courses in organization, production control and accounting give the student the theoretical background and some of the techniques needed in systems work. But the student needs a specific course in systems and procedures to give him a proper perspective and the applied techniques which he will need in his future work. The course should give him both a method of analysis directed at systems as such and an operating familiarity with the equipment that is available to make a system a reality.

Systems work should and will become a new area for direct employment for graduating industrial engineers. At present there are three types of generally recognized jobs where an industrial engineering degree is a sufficient prerequisite for employment: time study, production control, and statistical quality control. Each of these represents an area where the young industrial engineer may grow and advance in a company and make a substantial contribution. Systems work will open a fourth area where the graduating industrial engineer will find direct employment, thus making the profession more flexible. The new type of job itself has a bigger perspective than the present standard industrial engineering position. In systems work a man must bring to bear all the considerations that go into a company's policies — in short the whole rounded area of industrial engineering thought. Systems work is the only field where the graduating industrial engineer can directly practice his new found knowledge of organization and management. It is also his best entrance into a managerial position, for systems work is executive training with responsibility.

The profession of industrial engineering today is experiencing a growth in perspective. It is a profession that has not settled down and it is constantly asking where it is going and what should it do. This may be seen in the many articles appearing in this journal and other publications recommending some new direction to the profession. This is healthy and reflects the dynamics of our industrial civilization. The members of the profession offer their service as specialists in diagnosing and curing industrial and organizational ills, to restore or create efficient productive operations gauged by the criteria of financial and operating success. Our goal should be, as it were, to become the doctors and guardians of industrial organizations. And to do this the profession must be the repository of the basic skill and knowledge needed to g i v e modern organizations healthy systems. For every organization must have its network of procedures and the system itself molds, limits and directs the institution in whose sinew it is the operating nerve center. To sum up colloquially, you can't beat the system. It seems appropriate that at this point in the development of the profession of industrial engineering and the expansion in the still underdeveloped field of systems work that a mutually beneficial marriage between the two should take place. The study and solution of systems should become a major area of our work.

### REFERENCES


[1] Richard F. Neuschel, **Streamlining Business Procedures**, McGraw-Hill, N. Y. 1950. p. 3.

[2] Ibid, p. 10.

[3] Seymour Melman, **The Rise of Administrative Overhead in the Manufacturing Industries of the United States, 1899-1947**, Oxford Economic Papers (New Series) Vol. III, No. I., Jan. 1951, Oxford, England. p. 66.

[4] The Systems and Procedures Association of America, P. O. Box 96, Madison Square Station, New York, N. Y. Founded in 1946 and presently has some 1,000 members in 20 chapters throughout the United States.

[5] Shannon & Weaver, **Mathematical Theory of Communication**, University of Illinois Press, Urban, Ill., 1949.


[6] Approximately 90% of the schools teaching industrial engineering include a special course covering Systems whether directly in the I.E. department or in another division. From a survey of the 1952 catalogues of all schools offering an industrial engineering curriculum.

## Book Review

*"The Writings of the Gilbreths,"*

edited by William R. Spriegel and Clark E. Myers, Richard D. Irwin, Inc., Homewood, Illinois, 1953, 512 pages, $7.35

— by Robert M. Eastman, Associate Professor of Industrial Engineering, Georgia Institute of Technology

An occasional review of the writings of the pioneers of scientific management helps an industrial engineer keep his long range perspective amid the constant heavy pressure of immediate problems. The authors and publisher have done our profession a service in collecting and reprinting the works of Frank and Lillian Gilbreth. All their major ideas are here as the editors have deleted only duplicating material and outdated practical applications. As a result, the industrial engineer can read for himself the ideas which the Gilbreths expounded for extending the usefulness of scientific managment and applying it to the needs of an increasingly industrialized society.

The format and type face are especially easy to read. Irwin reports that the body type is 12 point Garamond No. 3 leaded one point. It sets 2.5 characters per pica against 2.4 for the usual type face. In this reviewers' opinion the slight extra cost is more than offset by the legibility of the reading matter. With spiraling printing and distribution costs, many publishers seem to have neglected to maintain the legibility of type face and format.

This work enables the industrial engineer to have in one volume the Gilbreth's writings which were so important to the development of his profession.

# RANDOM RATIO—DELAY[1]

By G. Eric McAllister

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*Preface: This paper outlines the statistical methodology for random sampling in ratio-delay, and assumes the reader's familiarity with the basic nature and reasons for making a study of this type. This paper is intended to translate fundamental statistical theory into a practical methodology for practicing engineers. It is believed that the methods prescribed are simple and easy to carry out, yet are consistent with mathematical theory. The first four sections of the paper require no mathematics beyond arithmetic and the analysis in section five is self-contained.*

Ratio-delay is a sampling technique which is used to estimate the percentage of time that a given machine or other industrial operation is delayed due to some clearly defined cause. The following procedure for taking a ratio-delay study has been proved [2] to be mathematically and statistically sound, and can be shown to be theoretically more accurate and practically more applicable than most existing ratio-delay techniques. The procedure below is outlined for taking ratio-delay readings of one machine or other industrial operation, but may be repeated to sample any number of machines or other operations. It is essential to maintain the order in which the following five steps are performed.

## I. STATE EXPLICITLY THE TIME POPULATION

The first requisite step in any sampling procedure is to give an explicit statement of the population (or universe) from which the sample is to be drawn. Thus, the first step in taking a ratio-delay sample is to list exactly all these minutes during [3] the total time period to be studied, when the plant is working. Let us suppose that your plant works [4] from 8 a.m. to 12 noon and from 1 p.m. to 5 p.m. This first rule is satisfied if you list in chronological order every minute from 8 a.m. Monday to 5 p.m. Friday, excluding known rest periods and lunch hours (12 noon to 1 p.m. daily) and the night hours (5 p.m. to 8 a.m. daily). The importance of clearly stating the time population beforehand cannot be too strongly emphasized in this or any other sampling problem.

## II. CONSECUTIVELY ORDER THE N ELEMENTS OF THE TIME POPULATION:

An "element" of the time population has been chosen as a minute (cf. footnote 3), and it is assumed that there are N such minutes in the time population. For a ratio-delay study, chronological order satisfies this requirement of consecutive ordering of the N elements of the time population. In the example which we are considering, we may code the times as M800 for Monday 8 a.m., and M801 for Monday 8:01, and so on. This ordering may be continued as follows (where dots represent o b v i o u s omissions): M800, M801, M802, . . . M858, M859, M900, . . . M1158, M1159, M100 [5], M101, M102, . . . M458, M459, Tu800 [5], Tu801, Tu802, . . . Tu1159, Tu100, . . . Tu459, W800, . . . F458, F459. This ordering gives us a time population of N elements (in this example, these elements are minutes), and our sample will be drawn from these minutes. If the working hours in another plant differ from those given in the above example, the consecutive numbering is, of course, based on that time population which was chosen under Step I.

## III. DRAW A RANDOM SAMPLE OF SIZE n FROM THESE N ELEMENTS:

Under this section, two alternate methods are presented for drawing a random sample of size n. These methods differ in practice, but are theoretically identical, and both are theoretically accurate.

### III-A. CARD RANDOMIZATION:

The general rule for card or ticket randomization is to obtain N identical cards, label them, and then select a sample at random. In the example of "your plant" this entails the acquisition of N identical cards. On each card, write one and only one of the elements (minutes) of the ordering of Step II. Thus, label the cards as M800,, M801, M802, . . . and so on.

Shuffle or otherwise mix these cards thoroughly. Probably this can best be done by obtaining a large drum or other container in which the numbered cards can be mixed so as to completely lose t h e i r previously established consecutive chronological ordering. Now draw one card from your container at random — that is, so that every card in the drum has an equal chance of being chosen. Record the time of this card. *Replace the card.* Thoroughly mix all the cards in the container again. Draw one card from the container at random. Record. Replace. Mix. Draw. Record. Replace. Mix. Draw. Record. . . . and so on until you have recorded n times. If, in an example, you wanted, for instance, 100 readings, then you will repeat this process 100 times, and you will complete this third step (using alternative III-A), with a list of 100 random times.

### III-B. TABLE RANDOMIZATION:

The general rule is to obtain a table of random numbers (such as the random number table in this paper or other table of random numbers in current statistical textbooks [6]), and choose random elements from the time population according to the numbers in this table. From any arbitrary starting number in the table, read the digits either horizontally or vertically. If you plan your observations one week at a time, then associate the numbers 1 and 2 with Monday, 3 and 4 with Tuesday, and so on throughout the week. (If you plan your observations two weeks at a time, then 1 would be associated with the first Monday, 2 with the second Monday, 3 with the first Tuesday, 4 with the second Tuesday, and so on.) For the hours, associate 8 a.m. with the number 8; 9 a.m. with 9; 10 a.m. with 0; and 11 a.m. with 7; associate 1 p.m. with 1; 2 p.m. with 2; 3 p.m. with 3; and 4 p.m. with 4 (note that we have not associated any hour with the numbers 5 and 6). For the minutes, associate the next two numbers with themselves. Now consider the following list of random digits: 3 8 1 8 8 0 3 6 1 5 9 8 7 5 8 1 6 6 1 5 1 0 1 3 5 3 0 2 4 1 5 2 6 1 4 9 1 . . . Let us begin to set up your required really random ratio-delay sample for one week from this list. The first number is associated with the day of the week; thus, the first random number 3 is associated with Tuesday. The next number is associated with the hour within Tuesday; thus, the second random number 8 is associated with 8 a.m. Since the next random number is 1 and the next is 8, our random ratio-delay readings will be taken on Tuesday at 18 minutes after 8 a.m. Record Tu818 on a separate sheet of paper. The next number 8 is associated with Thursday, the 0 with 10 a.m., the 3 with 3 and the 6 with 6; hence, the second random time to be recorded is Th1036. The next number 1 is associated with Monday. But the next number is 6 and 6 is not associated with any hour; so we must pass on to the next number 9 which is associated with 9 a.m. The next number is 8 which is omitted, then the next number is 7 which is passed over again; the next number is 5 and the next is 8 which are both taken, and thus the third time recorded is Monday at 58 minutes after 9 a.m.; or, that is, M958. Continuing with this list of random numbers, the fourth random time is M151 and the fifth random time is F135, and so on until you have obtained n random times. Thus, in our example, you will complete this

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[1] ILRP Research Report No. 12, prepared while under contract with the Office of Naval Research, Logistics Branch. The author wishes to express his sincere thanks to Ross Nelson, Mel Salveson, Al Rowe, and Joe Carrabino.

[2] See, for example, the ILRP Research Report No. 5 and 11.

[3] In place of minutes you may also use seconds, 30-second intervals, two-minute intervals, or other short discrete periods of time.

[4] In each of the five steps of this paper, we shall give a general rule first, and then apply this generalization to a hypothetical plant, called "your plant." Thus, the last part of each section will present the details of a complete random ratio-delay study. These details may be altered in accordance with the general rule of that section to conform to the immediate exigencies of each such study.

[5] Note that no minute between 12 noon or 1 p.m. can be listed because these do not appear in our time population. Similarly, no minute between 5 p.m a.nd 8 a.m. can appear.

[6] cf. Dixon and Massey, **Introduction to Statistical Analysis**, pp. 290-4; Deming, **Some Theory of Sampling**, p. 593.

**TABLE OF RANDOM DIGETS***

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 40681 | 27353 | 22597 | 88915 | 79178 | 81568 | 96319 | 51098 | 71270 | 63812 | 77365 |
| 89713 | 63020 | 45133 | 71152 | 54318 | 33657 | 45481 | 41509 | 04687 | 33262 | 98564 |
| 94563 | 84957 | 44619 | 79713 | 09949 | 65244 | 53466 | 55985 | 27077 | 81993 | 37171 |
| 43027 | 68321 | 02813 | 47446 | 08517 | 28803 | 96663 | 86674 | 67775 | 55543 | 00487 |
| 51194 | 79763 | 80567 | 62318 | 21551 | 41301 | 24034 | 29986 | 79315 | 61613 | 83115 |
| 67373 | 65291 | 63392 | 50049 | 64763 | 77384 | 69945 | 86642 | 49238 | 31727 | 79092 |
| 13011 | 44976 | 94731 | 44841 | 58114 | 02487 | 68308 | 63610 | 64436 | 79719 | 86555 |
| 75053 | 10760 | 56728 | 67907 | 73573 | 06858 | 89809 | 12729 | 13637 | 70054 | 93351 |
| 09416 | 07842 | 61398 | 82483 | 92684 | 53713 | 96476 | 13096 | 08892 | 29976 | 77773 |
| 08140 | 19067 | 07653 | 11476 | 57271 | 28172 | 20924 | 86795 | 80075 | 74483 | 76172 |
| 03614 | 04739 | 91340 | 60151 | 25949 | 13799 | 24239 | 37699 | 61160 | 65534 | 91260 |
| 51781 | 71407 | 97071 | 01707 | 52119 | 71110 | 83590 | 08030 | 00655 | 26829 | 89420 |
| 74840 | 30355 | 24811 | 91014 | 44450 | 53425 | 76329 | 88396 | 25471 | 24939 | 08916 |
| 17855 | 86450 | 13831 | 52245 | 61860 | 99428 | 74067 | 55408 | 52533 | 50065 | 63352 |
| 01207 | 28820 | 12109 | 62958 | 47884 | 88216 | 55819 | 09726 | 67161 | 38420 | 02415 |
| 29475 | 55575 | 37654 | 91091 | 33918 | 95562 | 68096 | 03709 | 34564 | 53896 | 34367 |
| 87008 | 92552 | 81623 | 12154 | 48696 | 96053 | 47245 | 69520 | 09495 | 97197 | 35893 |
| 24644 | 01087 | 32311 | 77807 | 56658 | 93684 | 33336 | 01512 | 39831 | 85626 | 23779 |
| 46326 | 03892 | 41967 | 94372 | 32998 | 58406 | 24326 | 88509 | 63328 | 21618 | 27759 |
| 25039 | 83375 | 32560 | 11945 | 50878 | 87600 | 66917 | 92413 | 00939 | 75858 | 26314 |
| 51940 | 44169 | 83459 | 88888 | 07752 | 23211 | 26260 | 08693 | 29368 | 99956 | 84758 |
| 65375 | 34741 | 99245 | 09156 | 83529 | 61952 | 83897 | 09931 | 76427 | 69486 | 88548 |
| 93919 | 72535 | 35297 | 38351 | 69774 | 61954 | 53808 | 51707 | 61318 | 15122 | 88657 |
| 32641 | 23240 | 37340 | 36135 | 25186 | 02274 | 25956 | 08937 | 31372 | 06943 | 96504 |
| 40131 | 51356 | 32702 | 75474 | 84559 | 53684 | 28758 | 39890 | 72112 | 15426 | 69659 |
| 65093 | 45655 | 00947 | 97180 | 35175 | 46277 | 19665 | 24873 | 75652 | 72660 | 24978 |
| 91020 | 86594 | 87835 | 53859 | 59205 | 22739 | 94579 | 69359 | 17526 | 57074 | 49443 |
| 89051 | 71343 | 26912 | 15341 | 31812 | 05179 | 17404 | 23642 | 30470 | 35331 | 43174 |
| 66627 | 47292 | 87259 | 27395 | 34567 | 98159 | 40764 | 95925 | 13833 | 63765 | 15378 |
| 07313 | 43774 | 88701 | 56132 | 36069 | 16027 | 05491 | 37788 | 27276 | 57333 | 02761 |
| 13840 | 83975 | 89909 | 88547 | 08856 | 37066 | 42128 | 07117 | 10909 | 68721 | 99323 |
| 56422 | 38011 | 10458 | 65809 | 15295 | 99155 | 01271 | 36612 | 93163 | 18865 | 68112 |
| 75812 | 82841 | 99809 | 33958 | 03468 | 98967 | 60237 | 86604 | 34209 | 87042 | 52709 |
| 78396 | 28235 | 26532 | 83318 | 77096 | 36217 | 99285 | 32993 | 85093 | 53164 | 28178 |
| 77050 | 98159 | 56449 | 08000 | 65445 | 38130 | 72304 | 32656 | 58223 | 09472 | 23042 |
| 45534 | 45029 | 84611 | 04753 | 49955 | 10020 | 56276 | 90596 | 89037 | 18424 | 94292 |
| 97612 | 39593 | 89037 | 03471 | 76022 | 08527 | 21418 | 56626 | 24739 | 06594 | 44200 |
| 95835 | 42224 | 66513 | 35514 | 19282 | 86647 | 84339 | 33670 | 50372 | 38939 | 41949 |
| 34916 | 94718 | 93210 | 03218 | 92353 | 34164 | 55546 | 57339 | 89379 | 94890 | 77096 |
| 46632 | 41268 | 35295 | 93493 | 61016 | 32761 | 10767 | 22685 | 50950 | 74885 | 64554 |
| 01487 | 64386 | 02269 | 15196 | 93712 | 61311 | 10786 | 18485 | 81751 | 28908 | 77870 |
| 44214 | 71437 | 59037 | 12657 | 80005 | 17106 | 78682 | 91223 | 82971 | 78688 | 84475 |
| 90468 | 99815 | 78139 | 69224 | 02220 | 59965 | 69932 | 79094 | 04080 | 66786 | 28460 |
| 74232 | 24251 | 70330 | 91262 | 09355 | 68912 | 96661 | 67153 | 13462 | 29941 | 39485 |
| 92253 | 94384 | 36540 | 11770 | 76555 | 77366 | 83318 | 75211 | 83624 | 32330 | 75513 |
| 53662 | 22108 | 08697 | 50312 | 91726 | 37906 | 10009 | 28915 | 25505 | 75795 | 35914 |
| 15458 | 76661 | 02770 | 47195 | 68630 | 08611 | 30428 | 16774 | 55857 | 73460 | 02840 |
| 53020 | 68646 | 01282 | 42227 | 39343 | 72195 | 32849 | 66381 | 88405 | 87540 | 34617 |
| 28256 | 03411 | 92796 | 77002 | 07332 | 05353 | 45197 | 37779 | 89154 | 38303 | 70620 |
| 87490 | 35299 | 62241 | 27197 | 04170 | 36179 | 59465 | 39318 | 01340 | 85298 | 70445 |
| 00958 | 98267 | 66174 | 28926 | 99547 | 16627 | 45515 | 67953 | 12108 | 57846 | 09578 |
| 30346 | 26957 | 78240 | 43195 | 24837 | 32511 | 70889 | 22070 | 52622 | 61881 | 91202 |
| 14056 | 57841 | 00833 | 88000 | 67299 | 68215 | 11374 | 55624 | 32991 | 17436 | 70218 |
| 96789 | 22551 | 12111 | 86683 | 61270 | 58036 | 64192 | 90611 | 15145 | 01748 | 05326 |
| 12633 | 15075 | 47189 | 99951 | 05755 | 03834 | 43782 | 90599 | 40282 | 51417 | 71196 |
| 25893 | 57092 | 76396 | 72486 | 62423 | 27618 | 84184 | 78922 | 73561 | 52818 | 33377 |
| 13092 | 50817 | 46109 | 17469 | 32483 | 09083 | 76175 | 19985 | 26309 | 91536 | 85950 |
| 72872 | 54109 | 74626 | 22111 | 87286 | 46772 | 42243 | 68046 | 44250 | 42439 | 19050 |
| 20724 | 19944 | 34450 | 81974 | 93723 | 49023 | 58432 | 67083 | 36876 | 93391 | 13078 |
| 37009 | 52173 | 36327 | 72135 | 33005 | 28710 | 34710 | 49359 | 50693 | 89311 | 84989 |
| 25961 | 70386 | 74185 | 77585 | 84825 | 09934 | 99103 | 09325 | 67389 | 45869 | 90776 |
| 73962 | 47022 | 12296 | 41623 | 62873 | 37943 | 25584 | 09609 | 63360 | 47270 | 52217 |
| 63164 | 76372 | 90822 | 60280 | 88925 | 99610 | 42772 | 60561 | 76873 | 04117 | 58309 |
| 05366 | 00082 | 72121 | 79152 | 96591 | 90305 | 10189 | 79778 | 68016 | 13747 | 95840 |
| 15902 | 61363 | 95268 | 41377 | 25684 | 08151 | 61816 | 58555 | 54305 | 86189 | 34941 |
| 53845 | 17851 | 92603 | 09091 | 75884 | 93424 | 72586 | 88903 | 30061 | 14457 | 38621 |
| 31694 | 55633 | 18813 | 90291 | 05275 | 01223 | 79607 | 95426 | 34900 | 09778 | 44454 |
| 23016 | 96567 | 38840 | 26903 | 28624 | 67157 | 51986 | 42865 | 14508 | 49315 | 16329 |
| 17292 | 18430 | 05959 | 33836 | 53758 | 16562 | 41081 | 38012 | 41230 | 20528 | 86488 |
| 75365 | 99837 | 85141 | 21155 | 99212 | 32685 | 51403 | 31926 | 69813 | 58781 | 47193 |
| 89013 | 86492 | 75047 | 59643 | 31074 | 38172 | 03718 | 32119 | 69506 | 67144 | 66959 |
| 44551 | 77837 | 30752 | 95260 | 68032 | 62871 | 58781 | 34143 | 68790 | 69766 | 80290 |
| 49675 | 13139 | 22986 | 82575 | 42187 | 62295 | 84295 | 30634 | 66562 | 31442 | 43247 |
| 40789 | 73539 | 99439 | 86692 | 90348 | 66036 | 48389 | 73451 | 26698 | 39437 | 29518 |
| 64086 | 82765 | 20389 | 93029 | 11881 | 71685 | 65452 | 89047 | 62669 | 02656 | 67267 |
| 79143 | 31528 | 39249 | 05173 | 68256 | 36359 | 20250 | 68686 | 05947 | 09335 | 56101 |
| 28231 | 07703 | 96777 | 33605 | 29481 | 20063 | 09398 | 01843 | 35139 | 61344 | 25755 |
| 76327 | 50155 | 04860 | 32918 | 10798 | 50492 | 52655 | 33359 | 94713 | 28393 | 84438 |
| 05428 | 65225 | 64285 | 86579 | 77447 | 75313 | 35762 | 45824 | 21535 | 48707 | 84917 |
| 56800 | 69853 | 75583 | 38682 | 55733 | 98453 | 35129 | 73541 | 62087 | 36549 | 77455 |
| 96180 | 50261 | 88659 | 11717 | 88909 | 87891 | 16709 | 97814 | 26600 | 79266 | 87911 |
| 52712 | 95148 | 66398 | 07111 | 89741 | 03758 | 42184 | 67000 | 66680 | 61277 | 17668 |
| 76869 | 19027 | 12764 | 32712 | 60671 | 98845 | 81227 | 38052 | 48243 | 91867 | 33577 |
| 50472 | 24399 | 17313 | 79665 | 07409 | 73900 | 66673 | 58861 | 08168 | 10289 | 81438 |
| 77168 | 64382 | 26927 | 54318 | 51043 | 03482 | 76777 | 27319 | 78196 | 16909 | 05483 |
| 79482 | 10156 | 87785 | 49603 | 85048 | 63090 | 60719 | 29756 | 10696 | 75713 | 64530 |
| 97826 | 82559 | 69027 | 41569 | 05422 | 47286 | 97825 | 15559 | 43482 | 07676 | 88766 |
| 90872 | 36839 | 01840 | 14860 | 76529 | 55890 | 12228 | 33910 | 26878 | 88758 | 26318 |
| 68457 | 71054 | 94300 | 18582 | 55813 | 26346 | 68685 | 24920 | 36374 | 98802 | 45556 |
| 35973 | 75910 | 16921 | 48284 | 48074 | 01401 | 10518 | 25359 | 52702 | 82966 | 70172 |
| 32091 | 50229 | 65799 | 13777 | 93030 | 53615 | 17057 | 07212 | 75930 | 56604 | 10750 |
| 81440 | 18180 | 68025 | 89261 | 65881 | 32138 | 73735 | 78459 | 74164 | 18466 | 42203 |
| 83893 | 89983 | 95140 | 40089 | 21441 | 39173 | 46895 | 16136 | 92301 | 33754 | 69216 |
| 64000 | 19357 | 74288 | 60608 | 49826 | 78374 | 72191 | 94337 | 24234 | 44821 | 15469 |
| 48420 | 68527 | 28646 | 44721 | 81925 | 48579 | 35499 | 63475 | 95235 | 51410 | 78863 |
| 96237 | 34204 | 08890 | 41795 | 28507 | 83735 | 82390 | 49173 | 80738 | 89279 | 77883 |
| 13429 | 41773 | 59936 | 30327 | 76898 | 96866 | 22721 | 96619 | 20297 | 01714 | 55140 |
| 20753 | 52940 | 49246 | 73092 | 81744 | 00189 | 60064 | 57631 | 77199 | 82742 | 36056 |
| 63752 | 93547 | 77926 | 16709 | 05242 | 91269 | 52190 | 47481 | 82784 | 61238 | 16369 |
| 44415 | 49199 | 55899 | 09790 | 70636 | 19057 | 51986 | 69657 | 79293 | 47793 | 47729 |

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third step (using III-B) with a list of 100 random times.

## IV. SAMPLE THE n ITEMS CHOSEN:

Chronologically order the n sample times you have obtained by the previous step (III), and take readings of the machine being studied at the random times selected. Before actually sampling the n items chosen, it is necessary to prepare a ratio-delay study sheet similar to the one illustrated below:

RATIO-DELAY STUDY SHEET

MACHINE: DATE:

| random time | setup time | uptime | downtime | | | | | miscellaneous with reason |
|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | |
| M807 | x | | | | | | | |
| M958 | | x | | | | | | |
| M1032 | | | | | x | | | |
| M1032 | | | | | x | | | |

Downtime 1 = no work available
Downtime 2 = no operator available
Downtime 3 = personal time of operator
Downtime 4 = other unavoidable delays
Downtime 5 = all avoidable delays

Now, enter your chronologically ordered random times in the left column of this study sheet. Each category must be carefully and unambiguously defined; these definitions should be known and understood both by the person taking the readings and by the person analyzing the results. A finer breakdown may be obtained, without increasing the number of columns on this sheet, by coding [7] the detailed reason and entering this code instead of your check or other mark in the appropriate column opposite the time observed.

You have now designed your ratio-delay experiment and are now in a position to leave your desk and carry out the ratio-delay study. Take snap readings of the machine being sampled at, or during, the minute recorded on the ratio-delay study sheet. A snap reading is an instantaneous observation of the machine being studied; and is obtained by proceeding to a vantage point from which the machine can be clearly observed, without looking at the machine, then glance at the machine for an instant, then look away from the machine and record on the prepared study sheet the information thus obtained. Let us suppose that the first few times in our sample are, say, Monday 8:07 a.m., Monday 9:58 a.m., Monday 10:32 a.m., Monday 10:32 a.m. . . . and so on. These times should have been listed down the left column of your ratio-delay sample sheet (as illustrated above). At exactly 8:07 a.m. on Monday morning you will take a snap reading of the machine being studied, and check or enter your code in the corresponding column of your sampling sheet, as to whether the machine is "up" or "down" and, if down, the rea-

[7] cf. coding in Morrow, **Time Study and Motion Economy**, p. 179.

son for the delay. Note carefully that you are scheduled to take two readings at 10:32 on Monday morning. (Made possible because of replacement of cards, or reappearance of the same sequence of random digits.) This means that you will take one snap reading at exactly 10:32 a.m. *but record the results of that reading twice,* as illustrated on the ratio-delay sampling sheet above.

**V. ANALYSIS:**

Because your sample was chosen at random, you are now theoretically justified not only in using the binomial distribution (this is the statistical term for using the estimates given below), for estimating the percentage of delay time, but also using this binomial distribution for estimating the standard error or the variance [8] of your estimate of percentage delay time. The binomial distribution may be used as follows: If r is the number of down readings out of a total of n readings, then the binomial estimate of the population downtime percentage is:

$$p = \frac{r}{n}$$

and the variance of this estimate is:

$$s^2 = \frac{pq}{n}$$

where $q = 1-p$. If n is large (say, n is greater than 50) then you may use the normal approximation (this is the statistical term for what is done next as interval estimation) to give you an interval estimate of the true percentage delay; that is, you may now say that almost always (99% of the time) the unknown true percentage will be within 3s of the number $p = (r/n)$. Statisticians say that $p = r/n$ is a point estimate of the percentage downtime; meaning that this p is the best single real number (point) for estimating percentage downtime. Statisticians define a 99% confidence interval estimate as the set of all those real numbers between $p-3s$ and $p+3s$; meaning that this interval $(p-3s, p+3s)$ will cover the unknown true percentage downtime almost always (99% of the time).

In the above paragraph on analysis, we have talked about percentage delay, but this can obviously be extended to compute point and interval estimates for the percentage delay due to personal time, no work available, and so on. It is important to notice that the "bi" of the word binomial requires a yes-no situation; obtained from the information on the ratio-delay study sheet by letting r be equal to the number of readings in the column of interest and by letting n be equal to the total number of readings in the sample. Thus, for example, we may binomially analyze personal time by letting r be the number of *personal* readings (downtime 3 on our study sheet), and by combining set-up and up-time together with all other down-time to be the *not-personal* readings; thus, n equals the number of personal readings plus the number of no-personal readings; which means that n must be the total number of readings in the sample, since each reading appears in one and only one column of the sample sheet. Then, $p = (r/n)$ is our point estimate of the percentage of time that this machine is down due to personal time of the operator, and the confidence interval $(p-3s, p+3s)$ will cover the unknown true percentage of personal time almost always (99% of the time).

The approach of the Industrial Logistics Research Project to the problems of work sampling (see, for example, ILRP's circulated discussion papers and research reports on Work Sampling) has justified the mathematical and statistical basis for the above design and analysis of random sampling in ratio-delay experimentation and has shown that the precautions and complications of current ratio-delay theory are usually unnecessary and sometimes even incorrect. It is therefore recommended that the above highly simplified and mathematically-sound ratio-delay experimentation methodology be adopted by the practical practicing work sampler, thus making ratio delay theory sounder and more accurate as well as making its application easier and more practical.

[8] We are only considering observations taken during a fixed period of time, and hence, this model does not consider variation from time period to time period.

## IN PERSPECTIVE — "HOW SAVE TIME!"

*(Editor's Note)*

The manner of thinking that Industrial Engineers use in their everyday work is often quite bewildering to the layman. The following material, which appeared on the editorial page of the PROVIDENCE JOURNAL in 1948, was called to our attention by Harold R. Nissley. We think you will enjoy it.

"Time is the most precious fluid in existence because it can be neither produced nor stored. We have an allotted span of time to accomplish our life's work; any loss from it is irreplaceable. If someone wastes five minutes of our time, the effect is the same as if he had sneaked into our room five minutes before the predetermined moment of our death and murdered us in cold blood. He has in fact shortened our lives by five minutes, irretrievably . . . Very few research men usefully employ more than 40 per cent of their working time, and 60 per cent of their time is consumed by avoidable delays or motions which neither give relaxation nor contribute to the advancement of work . . ."

Time Saving in Research
by Johan Bjorksten, Ph.D.

Dear Doc:

Friend of mine sent me your interesting pamphlet on "How Save Time." Already profited by it. Look.

However, if you got no objection, like run through some your basic rules. Have high regard them, but think maybe you clear up few points; I be whiz-bang. Example. You say:

"(1) There is one best way of doing everything."

No argument. Nail banged square on head.

"(2) The best way of doing anything is always the sequence of the fewest therbligs."

Slight problem here. Have now spent 45 minutes trying to find out meaning therbligs. Also lost place in pamphlet.

"(3) Movements should be confined to the lowest possible classifications in order to reduce fatigue. . . . Movements of the eyeball up and down takes 10 per cent less time than movement of the head in the same angle."

Very helpful. I now read up and down instead of sideways. Get through reading in no time. Understand nothing, but have good feeling of accomplishment.

"(4) In motions, try to arrange work so that the forearm pivots about the elbow, and the need for lifting the elbow is eliminated."

Have arranged it. I now rest elbows in lap while typing. Have caught three left fingers between "qwertyuiop" and "asdfghjkl;" lines on keyboard half dozen times, but with aid of wife have extricated them and gone back to pivoting forearm about elbow.

"(5) To minimize search time, there should be a definite and fixed place for all tools and material."

Okay. Have definite place for tools and materials. But wife changes place. Uses my pencils and paper for grocery lists. Moves typewriter when dusting. Washes and hides ashtrays. Also has habit of sending out to cleaner hat I wear while typing. What go say, Doc?

"(6) Develop the habit of relaxing completely all muscles not currently needed . . . Never stand when work can be equally well carried out in sitting position, never make an avoidable motion; the arm not in use should hang down loosely . . ."

Tried it. Don't work. Reason: Need arms in typing, but not legs. Have let them hang loosely. Result: They fall asleep.

"(7) Hesitation must be analyzed, explained, eliminated . . . Average engineer or chemist when needing a material available at his working place, hesitates 1.5 seconds before he locates it: If this is repeated 10 times hourly, or 100 times per day, the time lost of this item alone is 51,000 seconds or 14 hours yearly per person."

Understand that cold. Good tip. No longer hesitate when seeking item. If want cigarette, reach for where it should be; if not there, smoke what put hand on, instead. As result have inhaled several dozen pencils and electric light cord, but figure time saved invaluable.

One more point. Note you not allow in basic rules for situation like following:

I prepare write column. Get set at kitchen table. Tools and materials at hand. Yell at wife: "Turn

(Continued on Page 23)

## Book Review

*"How to Control Production Costs,"*
by Phil Carroll,
McGraw-Hill Book Company, Inc.,
New York, 1953, 272 pages, $5.00
— by Robert M. Eastman, Associate Professor of Industrial Engineering, Georgia Institute of Technology

One result of ever-increasing industrial mechanization has been the steady increase in the ratio of overhead to direct costs. In this book, Phil Carroll tackles the management problem created by the lumping, averaging, and pro-ration of indirect costs which are substantial and real yet not directly assignable under present accounting methods. Although the author does not advance a completely stated theory, he does show how the answer lies in a detailed analysis of actual behavior of cost components. The industrial engineer can well utilize Mr. Carroll's ideas in setting standards for all types of costs and evaluating performance against them.

Mr. Carroll's style is a welcome relief from those of writers who believe that professional literature should be erudite and difficult. This volume is well written and quite readable. By drawing on his extensive experience, the author adds greatly to the reader's enjoyment and interest. Dont be fooled — there are many sound, original and useful ideas.

I heartily recommend "How to Control Production Costs" to all industrial engineers. Not only does Mr. Carroll include many currently useful ideas, but his ideas foreshadow coming changes in methods of cost analysis and control.

# A Reply to Davidson's Review of "WORK MEASUREMENT"

By Adam Abruzzi

Assistant Professor of Industrial Management, Stevens Institute of Technology.

Professor Davidson's review of my book, WORK MEASUREMENT, has been the most searching and thorough that it has thus far received. It highlights the fundamental problems of making inferences in applied science, particularly where there is a crucial intervention of purposive human behavior. This is all to the good since a searching discussion of these problems and their implications is long overdue, particularly in the field of work measurement, where they are only rarely even recognized to exist. It is in that spirit that I write this reply to Davidson's review.

The first major question raised by Davidson refers to criteria of statistical stability, with particular reference to the studies of local stability considered in the book. It is his contention that such criteria must be "statistically rigorous," which can only mean that he considers criteria like control limits to be purely statistical. *This is a completely erroneous though rather common conception.* Shewhart's original works, for example, make the point time and again that — even in the restricted area of product quality-control limits are essentially *economic* criteria intended to minimize the *costs* (defined in a generalized sense) of concluding erroneously that stability exists and of concluding erroneously that it does not exist. It is true, of course, that the criteria adopted are always some function of the sample and, ultimately, of the population variance (if and when a population has been shown to exist). But the function itself it ultimately based on empirical considerations and is intended to arrive at an optimum emperical result in a given environment.

With respect to work measurement problems, the optimization process involves considering human variables as well as physical and monetary variables. More precisely, the criteria of statistical stability in this case must consider the human, physical, and monetary costs of attempting to achieve a certain degree of stability. Now, it is conceptually possible to induce human beings to work in a completely random manner, thus achieving an idealized state of statistical stability. This would enable extremely precise predictions to be made, for example, about their production rates. Even if this were possible in practice, this complete standardization of human beings required (for that is exactly what it would mean) would involve a catastrophic cost in that workers would cease to be human beings, at least at the workplace.

The problem, then, is to balance the desirable goal of being able to make predictions with a useful degree of precision against the likewise desirable goal of allowing workers to retain their purposive identities, both as workers and as human beings. There is no general solution to this problem; the solution depends instead on the local environment, the nature of the plant and industry, management's goals, the workers' goals and so forth. In any event, the optimization process must be based on empirical considerations and involves obtaining a useful level of precise prediction subject to the restriction that workers should have some latitude in their work behavior.

This viewpoint is expressed time and again in my book and the criteria of stability used were *all* developed with this in mind. Also, these criteria are admitted to be tentative, requiring further validation in terms of extensive application. The book also underscores the need for developing criteria to fit local situations, claiming only that the criteria used seem to be appropriate to the operations considered, according to all available statistical and empirical evidence.

It should also be pointed out that a much greater departure from "statistical rigor" was made regarding the criteria of grand stability considered in the book. These criteria were developed from the same general viewpoint, applied to the operation as a whole rather than to the individual worker. As in the case of local stability, their limitations and the need for adapting the criteria to local situations is painstakingly explained and documented in the book, both statistically and empirically.

Another important fact should be noted about the concept of statistical stability. In effect, criteria of statistical stability are intended to determine whether a statistical distribution function exists, i. e., whether statistical theory can be applied to the problem at hand. It is therefore clearly inappropriate to use statistical theory (in the sense of applying purely statistical criteria of stability) to test an hypothesis which reduces itself to a question of whether or not statistical theory itself can be applied. This is as futile and meaningless as using a mathematical theorem based on a certain axiom to test the validity of the axiom. The criteria for deciding these questions must be external to statistical theory in the first case and to mathematics in the second, which means they must be empirical.

The immediate question, then, is deciding whether the observations obtained in a given problem can be concluded to be random samples from some statistical distribution function. Now, in applied science, it is never true that a set of observations is completely random, for there always exists some criterion of randomness violated by the observations (cf. the difficulty of generating a set of numbers that is even approximately random). Hence, the optimization process described above must answer the question as to whether the observations obtained can be considered for *empirical* purposes to be random observations from a statistical distribution function. As indicated above, these purposes are precise predictions subject to a restriction on the human, physical and monetary costs involved.

If criteria of statistical stability are developed from this viewpoint — which is the only meaningful viewpoint — then it is indeed possible for systems in which human beings have a vital role, such as industrial production rates, to be statistically stable systems. More than that, it is always possible by empirical action based, e. g., on criteria of stability to bring about such a system when it doesn't exist initially (this is essentially what standardization means).

It might be added that unless a statistically stable system can be considered to exist in some sense, precise statements cannot be made about the system involved. This question is of the utmost concern to econometricians, for example, who are often confronted with the so-called problem of identifiability (i. e., no unique statistically stable system can be considered to have generated an observed set of economic data). But it is not appropriate here to go into further details regarding this central problem of experimental inference. These details are to be found in the book which discusses this problem in careful detail in many places, particularly Chapter 5, pp. 71-74, Chapter 6, pp. 79-85, and Chapter 7, pp. 112-117.

The second major question raised by Davidson is concerned with the problem of whether operation elements are independent — a problem with crucial implications regarding the ability to develop element standard data. According to Davidson, the book ignores the fact that the data obtained in experimental work vary not only because of variations in the underlying variables, e. g., the elements, but also because of the measurement method. The fact cited is, of course, true of all applied science where it is always assumed (or should be) that the observed variable is made up of two components: the underlying variable and the measurement error which are often related in a complicated and obscure manner. The book not only does not ignore this fact; it actually gives it careful attention.

Thus, much of Chapter 13 is devoted to such questions as the relation:

(1) between the observed distribution characteristics and the sensitivity of the measurement method;
(2) the observed degree of variation and the magnitude of the underlying variable;
(3) the observed degree of variation and the sensitivity of the measurement method;
(4) the comparative accuracy and pre-

(Continued on Page 22)

# Organizational Field Studies At Columbia University

By David B. Hertz* and
Albert H. Rubenstein**

Field studies into organizational phenomena such as communication, decision-making, and small group operation were begun in the Industrial Department at Columbia in 1950. Since then staff members and students from the department and other departments in the university have engaged in field studies in seven industrial organizations under the writers' direction as part of the department's general program of research and graduate instruction in organization and management theory.

Initiation of this program of field research grew out of the earlier courses in Organization and Management [1] which had attempted to provide a strong theoretical framework in which the problems of industrial enterprise might be considered. Emphasis was placed on the ability of the industrial engineer to make decisions about organization and control of an enterprise on the basis of *quantitative* statements about the nature of organizational structure and operations. In order to make such decisions, he had to be able to make reliable and valid *measurements* of the structural and operating characteristics of human organizations, particularly industrial organizations.

Two kinds of variables appeared to be important in such measurements 1) those which described the *structural characteristics* of an organization — e. g. number and kinds of people, functional hierarchy, communication media, facilities, technological processes, etc. and 2) those which described the *operating characteristics* of the organization — e. g. communication channels used, rates and kinds of communication, decision-making procedures, turnover, absenteeism, rate of output, quality of output, etc.

These variables lead to two kinds of functions which the industrial engineer and manager must be able to perform: 1) *design* or organization of the structural characteristics and 2) *control* or administration of the operating characteristics. These two functions give rise to a need for basic information on the variables concerned: what are the components of organization, what are their design characteristics, how can they be combined effectively, how do these components interact, how do they change and change each other, what are their operating limits, etc.

Since the organizations or systems in which we were interested were composed either entirely or predominately of people, we turned to the social sciences for the kinds of information required for the teaching and performance of these functions. Such data were not then available in the literature of the social sciences, although a large number of theoretical, experimental, and field studies had already been performed and were currently under way in universities and other research organizations across the country. [2, 3]

During this period of searching the literature and visiting with many people from the social and natural sciences — psychologists, sociologists, anthropologists, biologists, mathematicians, etc. and from various areas of administration — business, public, educational, industrial, etc. we discovered that a number of techniques had been developed for obtaining information about organizations on a fairly rigorous basis. In addition, however, we found a great mass of data collected by some of these techniques, much of which was contradictory, inconclusive, collected in a non-rigorous fashion, or isolated in the file cabinets of the investigators and not generally available.

Our first attempt, in 1950 under a grant from Columbia's Council for Research in the Social Sciences, was to examine some of these data and to attempt to reconcile the findings which appeared to be pertinent to the same general problem — that of measuring group interaction (communication). It was hoped that these findings would begin to yield sufficient regularity so that some of the required design and control criteria could be formulated. This effort was instructive for us and for some of our students, but was not helpful in answering any of our original questions to our satisfaction.

Consequently, we undertook to commit our resources for a few years to designing and conducting our own field investigations built around a set of a very few general questions of the following kind: 1) what can be measured in an on-going organization that will help us to develop design and operating criteria for human-linked systems; 2) what techniques can be used for such measurements; 3) how "good" are the data which can be collected with the aid of these techniques; 4) do different instruments apparently measuring the same things support or contradict each other? etc. Following the asking of these general methodological questions, we became more specific and began to ask what we hoped were operational questions which would begin to lead toward the establishment of design and control criteria for such organizational phenomena as communication, decision-making, committee operations, etc.

The three sets of field studies described below were selected for presentation here because they were all performed by teams of graduate students (sometimes as many as 18 on a single study) under the direct supervision of the writers and they have all been or are currently being reported in the literature. Several dozen more studies in industrial and other organizations, using the same basic methodology were performed by smaller groups or individual students in the department's graduate courses and seminars in Organization and Management. Most of these have not been reported in the literature.

## COMMUNICATION STUDY IN A MANUFACTURING COMPANY [4]

Our original intention in undertaking this study was to become acquainted with the problems of measurement of communication in an operating organization, and to attempt to use some of the data-collection techniques developed by various social scientists. The initial study design called for the use of approximately 20 more-or-less formalized techniques for describing the organizational structure and the communication patterns of an on-going organization.

We had selected, as a focus for our investigation, a six-man suggestion committee representing several functional areas and levels of management. The make-up of the committe and the nature of their task — deciding on the merit of suggestions submitted by the plant's employees — suggested that a lot could be learned about the plant's communication systems by intensive study of these people both in committee session and in their day-to-day routine about the plant.

Shortly after the study began, the plant manager requested that we help him make a decision about the future of the suggestion system. He was dissatisfied with its operation and did not know whether to make a change in its operation, and if so, what kind of a change to make. His view of the functions of the suggestion *system* was: 1) to save money for the company and 2) to boost employee morale. He considered that the suggestion *committee* also had two functions. 1) to make decisions on the disposition of suggestions and 2) to indicate to the employees that they were being represented in this decision-making.

From these sets of objectives, a set of crude measures was developed and the investigation was modified to include instruments that would provide these meas-

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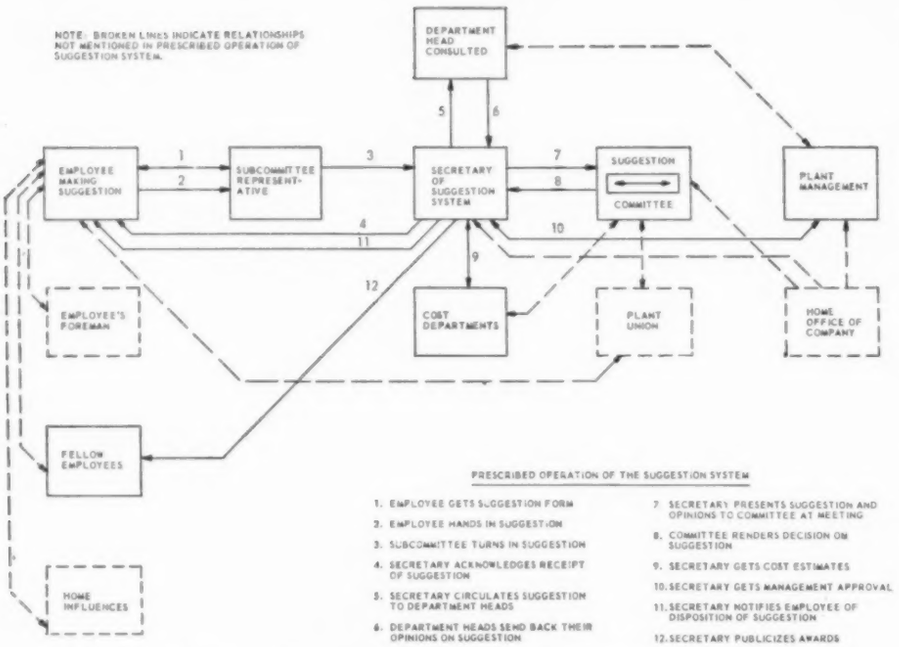
NOTE: BROKEN LINES INDICATE RELATIONSHIPS NOT MENTIONED IN PRESCRIBED OPERATION OF SUGGESTION SYSTEM.
DEPARTMENT HEAD CONSULTED
EMPLOYEE MAKING SUGGESTION
SUBCOMMITTEE REPRESENTATIVE
SECRETARY OF SUGGESTION SYSTEM
SUGGESTION COMMITTEE
PLANT MANAGEMENT
EMPLOYEE'S FOREMAN
COST DEPARTMENTS
PLANT UNION
HOME OFFICE OF COMPANY
FELLOW EMPLOYEES
HOME INFLUENCES
PRESCRIBED OPERATION OF THE SUGGESTION SYSTEM
1. EMPLOYEE GETS SUGGESTION FORM
2. EMPLOYEE HANDS IN SUGGESTION
3. SUBCOMMITTEE TURNS IN SUGGESTION
4. SECRETARY ACKNOWLEDGES RECEIPT OF SUGGESTION
5. SECRETARY CIRCULATES SUGGESTION TO DEPARTMENT HEADS
6. DEPARTMENT HEADS SEND BACK THEIR OPINIONS ON SUGGESTION
7. SECRETARY PRESENTS SUGGESTION AND OPINIONS TO COMMITTEE AT MEETING
8. COMMITTEE RENDERS DECISION ON SUGGESTION
9. SECRETARY GETS COST ESTIMATES
10. SECRETARY GETS MANAGEMENT APPROVAL
11. SECRETARY NOTIFIES EMPLOYEE OF DISPOSITION OF SUGGESTION
12. SECRETARY PUBLICIZES AWARDS

**Figure 1. Research Model of the Suggestion System**

ures. One of the first steps in the investigation was the construction of a communication model of the suggestion system, first as prescribed and visualized by plant management and then as it actually operated. *Figure 1* describes both the prescribed system (solid lines) and the additional groups involved in its actual operation, plus the communication relationships represented by these additional groups (the non-prescribed groups and relationships are indicated by dotted lines).

Among the techniques used for obtaining data pertinent to the measures of effectiveness were several kinds of interviews (Sociometric,[5] Critical Incident,[6] Non-structured); several questionnaires (Communication, [7] Error-Choice [8]); several methods of observing interaction in the committee sessions (Chapple-Arensberg Interaction Recording,[9] Bales Interaction Process Analysis,[10] Problem-Solving Analysis of Content); analysis of work flow and functional communication channels (Flow Process Charts, etc.); Analysis of the records of the plant and the suggestion system (output of committee, growth of the suggestion system, time-lags in the system, etc.); and collection of other data pertinent to the study (sampling of suggestion systems in other companies, search of public and company sources of information about the company and the plant with respect to labor relations, technological advance, etc.).

Some of the major findings are summarized here: 1) the secretary of the suggestion committee (and of the whole system) was found to play a dominant role in the deliberations of the committee and did in fact act as chairman, contrary to the intention of the initiators of the systems who prescribed that the secretary merely handle the paper work and read the suggestions at committee meetings; 2) the foremen of the various production departments who had been completely left out of the operation of the suggestion system were, in some instances, exerting an inhibitory effect on the employees with respect to submission of suggestions; 3) the first year of operation of the suggestion system showed a large financial loss and there did not appear to be any trend toward improving this condition; 4) the employees were not found to be generally well-informed about or pleased with the operation of the system even though a number of them, when questioned directly, said they thought the system was fine. Potential reasons for their attitude toward the system included: long lags in the system — particularly between the submission of a suggestion and the notification of the submittor as to its disposition; several incidents of questionable awards which were unfavorably viewed by a number of employees, foreman, and the union president; and a general lack of publicity about the system both within and outside the plant. 5) This latter finding — inadequate publicity — proved symptomatic of a general deficiency in public and employee relations on the part of plant management. A check of the company magazine (covering half a dozen branch plants), the local newspaper, and the company bulletin boards and other information media indicated a general lack of information and public relations effort about plant activities in general, including the suggestion system. Following the presentation of this finding to plant management, a personnel man was hired to handle employee activities and publicity as a full time job.

### Field Studies of Research Group Operations[11, 12]

This series of five field studies constituted one phase of a Study of Team or Group Research, undertaken for the Human Resources Division of the Office of Naval Research. The studies were designed and the pilot investigation was made in the Fall of 1951. The other four studies were conducted in the Spring of 1952. A total of 25 staff members and graduate students of the Industrial Engineering Department and several other departments in the university participated in the field work as part of the laboratory work in four graduate courses and seminars.

A total of nine research groups were included in the investigation, selected from five companies doing research and development work in Chemistry, Food Technology, Communications and several branches of Engineering.

The basic premise of the entire project was that a large proportion of the scientific research and development work currently under way in this country can most effectively be performed by integrated groups or teams of scientists, engineers, and supporting personnel working as units on common problems.

Such organization of the research activity depends on 1) careful selection and balancing of the members of these teams, 2) proper supervision, and 3) the provision and maintenance of communication channels that will encourage transfer of information to the team and between team members.

A critical element in the proper functioning of these teams was postulated to be their ability to obtain, interchange, and utilize information pertinent to the problem on which they are engaged. For purposes of the field studies, therefore, the research team was conceptualized as the focus of a communication net, each member representing a node with an intake and output function, linked to other nodes in the net and to a member of information sources outside the net, e. g. library, other groups, customers, etc.

The field studies were designed to investigate these linkages or *communication channels* in terms of their availability, ease of utilization, communication media employed, extent of actual utilization, and effectiveness in transferring information to the team members.

Each study lasted approximately six weeks, and employed three kinds of survey instruments: 1) A random sampling of communication activity over a five week period. The sampling periods were selected on a probability basis, after stratifying the interval into weeks, days of the week, and hours of the day. At the time indicated by the sampling plan, a member of the Columbia staff would enter the laboratory and hand each group member a check off form which requested the kinds of activity the member was engaged in during the immediately preceding fifteen minutes (working at the bench, writing reports, etc.), the time spent on each activity, with whom he had communicated during that period, what the communication was relevant to, the medium used, and whether he had received any informa-

tion helpful on his project as a result of that communication. 2) A questionnaire administered near the beginning of the study which requested information on available communication channels and media, frequency of use of these channels and media, sources of information, difficulties in communication, and other information pertinent to the communication network of which the team was a part. 3) An interview, conducted at the end of the five week sampling interval, with the members of the team, their supervisors, and technical assistants. The interview provided additional information which was not readily obtained by the other methods, and gave the investigators an opportunity to clear up any inconsistencies in the data of the sampling or questionnaire, and to get some feedback on the methods they had been using for obtaining information.

The findings have been presented in detail elsewhere,[12] but the kinds of information yielded by these studies will be briefly indicated: 1) Sharp differences were found between the operating characteristics (in terms of communication and information transfer) of several groups having several organizational features in common-size, type of work, number of members — but differing in certain potentially critical features — age of the members, history and permanancy of the group, physical layout of the research facilities. 2) Several cases were found in a number of the laboratories studied, where certain information sources were not available to the team — notably contact with customers and suppliers, adequate central files on completed projects and general information, contact with other groups or departments in the organization. 3) Loss of time of professional research workers due to lack of communication facilities, inadequate technical assistance, and absence of a buffer between them and people from sales and production calling them on the phone or leaning over their shoulder to find out "when the project will be finished." 4) A number of valuable sources of information for group members were discovered which had not been recognized by some of the administrators and had therefore not been encouraged. 5) A general reluctance or inability on the part of some groups to produce adequate reports of their work when needed.

In addition to these general findings, a number of specific instances of communication blockages and absence of information sources were revealed by the studies. Two of the major problems in making field investigations of this type were pointed up by our experience in this set of studies. The first was the general problem of designing and conducting field investigations of interpersonal communication which includes such questions as: how to phrase the research questions in operational terms, what kinds of data should be collected, how reliable are the data collected by interview or questionnaire, how to sample the activity being studied to provide confidence in the representativeness of the findings (since you are sampling in a dynamic system through time), how to evaluate the errors, etc.

These and other similar questions led one of the writers to discuss the general problems of making such measurements in a field situation, in a memo to the staff,[13] and to conduct a seminar in the Fall of 1952 on the conduct of Organizational Field Studies. As part of the work of that seminar, the students undertook a field study of a purchasing department, which is described below.

The second problem was that of defining, in operational and meaningful terms such concepts as "information." The question arises as to the meaning of the statement "I received information when I spoke to Mr. A." The same writer is currently conducting the pilot phase of an investigation into the categorization and "measurement" of the kinds of information with which the research worker deals.

The instrument being employed in the pilot study is a fill-in questionnaire which has three questions. These three questions are to be answered immediately following an interaction event initiated by the research worker, involving a request for information. The three questions are: When you approached an information source for help; 1) What was the question you had; 2) Whom did you approach; 3) What was the result?

With a large number of such incidents on hand, from a large number of research laboratories, the investigator hopes to be able to begin "mapping out the message space" with which the research worker deals — that is, identifying the classes of messages which carry information for the research workers. This categorization should provide an important initial step in eventually "measuring" the flow of information to, between, and from research workers. (For a more detailed discussion of this concept of "kinds of information," see Chapter One of *Team Research*.[12]

**Effectiveness Study in a Purchasing Department** [14]

This study, performed in the purchasing department of a large engineering company, was undertaken as the laboratory work in a seminar on Methodology of Organizational Field Studies, one of a series entitled Theory of Organization and Management. It was the first of the field studies described here which included in its design a postulated functional relationship.

The study was designed around the hypothesis that there is a functional relationship between the effectiveness with which individual buyers and expediters do their jobs, and the rate, or amount, or volume of interpersonal communication they engage in beyond the specified handling of papers.

Five buyers and four expediters were selected from the purchasing department on the basis of a preliminary sample of the kinds of orders the fifty-person department was handling. They, along with all but ten of the other purchasing department personnel, were located in one large open room in a large loft building which housed several of the company's other departments.

In addition to a great deal of preliminary information required for designing the main part of the study, two basic kinds of data were collected to test the hypothesis: 1) observational data of the interpersonal communication involving the nine subjects over a two week period, and 2) department records on number of orders handled, time lags, errors, etc. over a one year period for the same nine subjects.

The preliminary phase took several weeks, during which department and other company records were sampled, company and department administrators were interviewed, the subjects were selected and asked to fill out questionnaires on their communication activity, and preliminary observations were made of communication in the purchasing department.

The observational data was taken by a member of the seminar who spent two full weeks in the department, observing the nine subjects for ten minute intervals, selected in advance for him by a probability time sample. In designing the sample, the investigators divided the two-week period into strata by week, day, and hour of the day, selecting the exact ten minute periods on a random basis, with the overall restriction that the sample be perfectly balanced according to individual subject, hour, day, and week.

The observational data included: all conversations, phone calls, meetings, or casual verbal interchanges involving the subject during the ten-minute period; the initiator; the medium used (phone, walking over to desk, etc.); the duration, the names of the other people involved; and which purchase order the interaction concerned. The latter two data were obtained by the observer immediately following the sample period, when he approached the subject, hitherto unaware that he had been under observation for the preceding ten minutes, and questioned him on these points.

The data on effectiveness was obtained from a random sample of purchase orders handled by the subjects. The principle datum employed in constructing the effectiveness measure was the time lag between placement of the order and its arrival at the company's receiving department. Other time data obtained included: the length of time required for a requisition to be turned into a purchase order, the variance between the time specified by the requisitioning department as "date required" and the actual date received, etc.

Analysis of the data is currently under way and it is expected that, although no clear functional relationship will be forthcoming in mathematical form, the two variables — interaction (communication) and effectiveness will serve to differentiate the nine subjects, and indicate a rough relationship between communication and effectiveness.

(Continued on Page 22)

## A REPLY TO DAVIDSON'S REVIEW OF "WORK MEASUREMENT"

(Continued from Page 18)

cision of different measurement methods when used under varying conditions and with elements and cycles of different kinds and magnitudes.

This chapter also points out that the question of whether elements, say, are independent may depend on the measurement method used. It is largely because of the relations described above, moreover, that the book strongly recommends in several places that the entity measured should be at least five times as great as the smallest measurement unit used.

Apparently one of the most important factors considered by Davidson in his appraisal is a single random set of data taken from one of the actual studies, which has an element whose mean time is between one and two hundredths. Davidson correctly points out that elements as short as this certainly could not have a normal distribution of time values, and the measurement method may in such cases have a direct effect on the question of whether the elements are independent. As indicated above, Chapter 13 in the book makes exactly the same points in its comprehensive treatment of the problem of making meaningful measurements of work.

The reason the element in question was considered, then, is not ignorance of the points Davidson raised. It was decided not to make any changes in the element definitions originally developed by the plant's time study staff to avoid the possible charge that the element definitions were manipulated so as to verify the author's preconceptions. It was crucial to retain the original element definitions for an even more important reason: the hypothesis that was to be tested was whether the times for elements as *currently defined* are independent; the book itself establishes that elements can be defined (by certain groupings) so as to be independent.

Even so, elements shorter than three hundredths comprised a small fraction of one percent of all the elements considered. Moreover, elements shorter than five hundredths comprised less than 5 percent of the elements considered. In fact, the median element time in individual operations was at least ten hundredths in most cases, with the largest element time ranging from about ten hundredths to thirty hundredths. Hence, the problem of extremely short elements was really of no significance in these studies. This is all the more true in view of the fact:

(a) that the elements in individual operations were tested simultaneously, and

(b) that independence was established in certain cases even with elements as short as three hundredths.

Davidson also raised certain other questions on whether the data considered were normally distributed and whether the central limit theorem cited in the book is sufficient justification for assuming normality. It is true that the central limit theorem is expressed in non-rigorous language; it seemed advisable to paraphrase the theorem in terms best understood by the engineer, giving references as to where a rigorous treatment could be found. It turns out that except for extremely short elements, element data are generally symmetrical and, in most cases, reasonably normal. (Nevertheless, for the sake of completeness, the book gives a reference to the test procedure that can be used for cases where normality cannot be assumed.)

But even if this were not true, it still wouldn't appreciably affect the conclusions reached on the subject of independence. The crucial question is not whether a normal distribution exists, but whether *some stable distribution* exists according to the criteria of statistical stability adopted. This is because it is quite possible to establish that a normal distribution exists with, say, a "goodness of fit" test and still not have a stable distribution (in the sense of random samples).

The result is that verifying that a stable distribution exists is much more useful in practice, especially since the test statistic will have approximately the correct distribution, even if the underlying population is not normal, provided that fairly large samples are taken. It is these facts that enable statistical theory to be successfully applied even to problems, like certain economic time series, where there isn't any possibility of checking on the assumption of normality.

It is clear, then, that the conclusions reached in the book regarding the independence of elements can be interpreted uniquely and were, in fact, interpreted correctly. It might be added that the probability values obtained were so small (less than .1 percent in many cases) that it is difficult to conceive of *any* distribution function which could be responsible for such great departures from the hypothesis of independence, even if all the questions considered above had been completely ignored. In addition to considerable statistical evidence, there exists another and decisive factor strengthening the conclusions reached: extensive empirical evidence cited in the book and elsewhere indicates that many elements as currently defined are not independent, with little or no evidence to the contrary.

Largely on the basis of the two major questions raised, Davidson concluded that there are important departures from the methods of statistical inference and, hence, crucial sacrifices in precision in WORK MEASUREMENT. This is simply not the case, as indicated above. The most important fact to be remembered is that statistical method is only an aid to the understanding of empirical phenomena and must not be applied blindly and dogmatically. This is an especially important precaution in an era where the dogma of statistics has become fashionable at the expense of making empirically meaningful inference.

## ORGANIZATIONAL FIELD STUDIES AT COLUMBIA UNIVERSITY

(Continued from Page 19)

### CONCLUSIONS

The series of field studies described above has served two purposes. It has provided the opportunity for staff members and students to conduct investigations of organizational phenomena in operating units, with no obligation to come up with answers to management problems. This has enabled the investigators to design and conduct studies that they were interested in and that they could learn from, without the pressure of having to produce a report to please a sponsoring agency.

Secondly, the field studies have provided the means for testing a number of survey techniques that have been proposed by social scientists and others for obtaining reliable, useful information in operating organizations. First hand experience with the usefulness and limitations of these instruments should help both staff and students to design and employ even better ones for future organizational studies. In addition, the investigations have shed some light on a number of the very difficult problems facing students of organization in attempting to construct and test a meaningful theory of organization.

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## PRESIDENT'S MESSAGE

(Continued from Page 2)

that the important talk he had come to hear had been cancelled when the speaker wired his regrets that he had lost his reservation out of Washington to some higher priority. Some people are also confused by a certain Federal department that sends agents throughout our land advising farmers how to increase their yield and at the same time employs other experts to set quota limits to avoid the farm surplus.

There are many problems that we need to solve, some of which we can and should work on. Others that appear beyond our current abilities should be filed for future reference. Daniel Starch had some very fine thoughts about these matters which were published ten years ago by Harper & Brothers under the attractive title of How to Develop Your Executive Ability. He starts out in a very pessimistic mood but finishes with a few paragraphs that are particularly worth quoting:

"The world is changing and if we are tempted by despair, let us remind ourselves that the world is what we make it, and that to the making we each contribute something. And therein lies our hope. Though life may be a struggle, it will not be without purpose.

"To hold yourself to your course and to keep going forward fix firmly in your mind these four cardinal principles:

1. In dark days dire prophecies are always made.
2. Nineteen out of twenty things you fear never come to pass, and the one that does come to pass is seldom as terrible as anticipated.
3. The most important element in human history is human nature. Within the time of recorded history, man has changed little.
4. Right ultimately prevails."

As your new president I am counting on each and every one of you to make this another year of substantial growth. Economically my barometer indicated stormy weather ahead. Our foundations are on good solid ground, hence all we have to do is to continue to build from the best design and with the best materials available.

## IN PERSPECTIVE— "HOW SAVE TIME"

(Continued from Page 17)

the _____ radio down!" Chase son who like bang * * * * sign on typewriter. Pull down shade so not to be distracted by blond across street. Open collar. Put on hat. Pivot forearms about elbows. All ready go . . . .

Doorbell rings. Wife's relatives come visit. What I do now?

Finally. Estimate, by eliminating nonessential words have saved 6½ minutes writing this column as opposed average column. All I want know now is what do with time saved? Wait hear from you. Meanwhile, I make drink for self.
M.J.O.

## Book Review

*"A Creed for Free Enterprise"*
By Clarence B. Randell,
Little, Brown & Company,
Boston, 1952, 177 pages
Reviewed by Wilson J. Bentley,
Associate Professor, School of Industrial Engineering and Management,
Oklahoma A. & M. College

This book is recommended reading for any thinking person in the field of education or in industry. Mr. Randell has a surprisingly good manner of expressing himself and gives the impression that he is speaking his mind to a group of business associates.

The author feels that the businessmen, by not writing about free enterprise, have missed their best opportunity to reach the general public. He says, "We (the businessmen) are critical that the American enterprise system is not taught in forthright fashion to the eager minds of the postwar student groups. But the faculties reply that there are no books on business written by businessmen to put on the shelves of their libraries. They rather reasonably ask why, if we hold such deep convictions, we do not put them in writing."

In the second chapter, the author stresses the fact that production is not synonomous with free enterprise, but is merely a tool to be used by society for its own advancement. "The secret of free enterprise," he states, "is that we harness the natural instinct of each man to serve himself, and rely on all other natural forces to see that as he serves himself, he serves society."

The third chapter entitled, "Unions Never Lose," is quite biased, although the author tries (unsuccessfully) not to be. He does feel that unions are here to stay, and must be honestly accepted as a permanent part of the industrial organization.

Mr. Randell's concepts of requirements for "The Boss" are sound and the chapter by that title is one of the better ones. His discussions of the businessman and his relationship with the community, with government, with universities, and with foreign policy are all interesting and certainly contain some good thoughts. He believes that community relations, lend-lease of businessmen to government agencies, and the support of private universities are a proper charge to the cost of production.

The beliefs of Mr. Randell on the subject of retirement age are briefly this: "For the wisdom jobs, the time and age should be 70; for the deciding jobs, 65." He has a good exposition on the importance of thought, coupled with the formulation and verbalization of ideas and ideals, as a necessity to the progress and growth of the individual and the organization.

This is not a book which can be given to all the foremen and expect them to read it, understand it, and then vote for free enterprise. It does furnish a good insight into the character of the author. For the reader who is, or has, experienced similar situations, it can be a valuable aid in confining or forming his own beliefs.

## Book Review

*"Simplified Drafting Practice"*
by W. L. Healy and A. H. Rau,
John Wiley & Sons, Inc.,
New York, 1953, 156 pages, $5.00
— by Robert M. Eastman, Associate Professor of Industrial Engineering
Georgia Institute of Technology

It is axiomatic in cost reduction that the largest savings are possible in activities which cost the most money. While industrial engineers have been focusing their attention on direct production with excellent results, the proportion of total cost going to indirect components has increased greatly. In many industries, the cost of engineering and drafting has been shooting up as shown by not uncommon ratios of one engineer to every eight or twelve employees.

The authors have based this volume on their work with General Electric Company in streamlining and simplifying drafting and engineering procedures. The principles of industrial engineering have been applied in eliminating useless work, combining operations and simplifying methods used. For example, in questioning the necessity of the drafting process, they found that freehand drawings are quicker and will serve many purposes just as well as an artistic instrument job. They have set up standard procedures, forms and instructions for repetitive engineering jobs.

Any industrial engineer who is concerned with reducing the high cost of engineering work will do well to read "Simplified Drafting Practice."


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